# Annual Technical Report

**Summary Descriptions of Research**
for the period **June 1, 1991**
through **May 31, 1992**





# Institute for the Study of Human Capabilities

## URI - AFOSR #90-0215

**Poplars Research and Conference Center**
**Indiana University**
**Bloomington, Indiana 47405**

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We continue to make significant progress toward our long-term goals. The Institute maintains an inter-laboratory, work-station based computer network. A third conference was held during this funding period, on March 25-27, 1992, again on the subject of Human Error. During the funding period, the university completed rehabilitation of three buildings for use in Institute-related research. Andrew Dillon, from the Human Sciences and Advanced Technology Research Institute in Loughborough, England, collaborated with several groups at the university on human-computer interactions. The institute has provided partial support of research leading to the publication, during the past year, of 46 journal articles and book chapters, and the presentation of 28 papers at meetings of scientific societies, described in this report.

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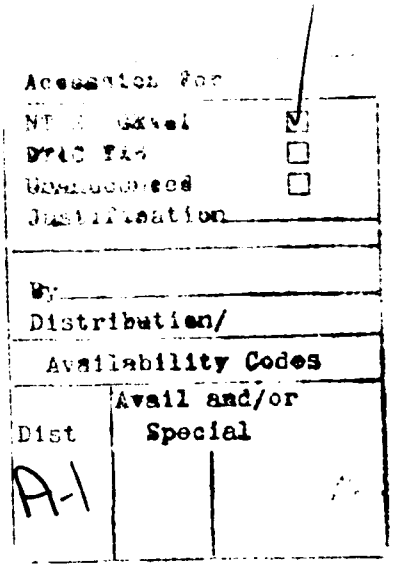


# Institute for the Study of Human Capabilities

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**Poplars Research and Conference Center**
**Indiana University**
**Bloomington, Indiana 47405**

# Table of Contents

# Annual Technical Report

## Summary

This Annual Technical Report of the URI/AFOSR-supported Institute for the Study of Human Capabilities, at Indiana University, describes work done from June 1, 1991 through May 31, 1992. The Institute currently consists of thirteen affiliated laboratories, in which research is conducted by eighteen faculty investigators and a considerably larger number of graduate research assistants, technicians, programmers, and other staff members. One of the primary goals of the Institute is to provide enhanced opportunities for interactions among these investigators, whose appointments are in six departments (Psychology, Speech and Hearing Sciences, Visual Science, Linguistics, Mathematics, Medical Science) and three schools or colleges of the University (College of Arts and Sciences, School of Optometry, School of Medicine). Another goal is to familiarize scientists who conduct basic research on sensory processing, cognition, and decision making, with current problems in the field of human factors, or human engineering. The Institute is also available as a source of technical or scientific advice for researchers in government or industry who are working in areas related to those represented in its laboratories.

We continue to make significant progress toward our long-term goals. The Institute maintains an inter-laboratory, work-station based computer network. This system has been in operation for the past four years and is now in regular use for the exchange of information and, in several laboratories, for data analysis, graphics, and modeling. Other ways that the Institute-affiliated faculty interact are by attending Institute-sponsored seminars presented by visiting scientists, through other interactions with these visitors, and through collaborative research. Funds made available through the Institute continue to be used to maintain, repair, and in some cases upgrade research apparatus in the affiliated laboratories. The Institute employs several part-time technicians, programmers, and graduate student research assistants who conduct research under the direction of the faculty investigators. One half-time computer systems administrator is employed who maintains the inter-laboratory computer network.

A third conference was held during this funding period, on March 25-27, 1992, again on the subject of Human Error. Neville Moray, from the University of Illinois, and C. S. Watson served as conference chairpersons. Other speakers included Andrew Dillon, Colin Drury, Earl Hunt, Barry Kantowitz, Raja Parasuraman and James Reason, and from Indiana University, A. Bradley, G. Bingham, G. Kidd, E. Thelen, and J. T. Townsend.

During this funding period, the University completed rehabilitation of three buildings for use in Institute-related research. Two of these buildings are an anechoic and an echoic chamber, each with associated control rooms, that were originally constructed as part of J.P. Egan's laboratory. The third building is a residence that has been modified to serve as a multi-station testing facility for Human Factors research.

One of the major goals of the Institute has been to appoint a Visiting Investigator in Human Factors to augment our basic-science oriented research staff. During the spring semester of 1992 (January-July), Andrew Dillon, from the Human Sciences and Advanced Technology Research Institute in Loughborough, England, served in this capacity. Dillon collaborated with several groups at the university on human-computer interactions, as described in detail in a later section. He also

completed a review of contemporary research on individual differences in cognitive and sensory abilities, with specific concern for the relevance of that research to human factors applications. A brief summary of that review is included.

The Institute, by these means, has provided partial support of research leading to the publication, during the past year, of 46 journal articles and book chapters, and the presentation of 28 papers at meetings of scientific societies.

# Personnel

Investigators

| | |
|---|---|
| Charles S. Watson, Ph.D., Director | Professor, Speech & Hearing Sciences<br>Professor (part-time), Psychology |
| Richard M. Shiffrin, Ph.D., Associate Director | Waterman Professor, Psychology and Cognitive Science |
| Arthur Bradley, Ph.D. | Assistant Professor, Visual Sciences |
| James C. Craig, Ph.D. | Professor, Psychology |
| S. Lee Guth, Ph.D. | Professor, Psychology and Visual Sciences |
| Larry E. Humes, Ph.D. | Professor, Speech & Hearing Sciences |
| David B. Pisoni, Ph.D. | Professor, Psychology and Cognitive Science |
| Robert Port, Ph.D. | Associate Professor, Linguistics, Computer Science, and Cognitive Science |
| Donald E. Robinson, Ph.D. | Professor, Psychology and Adjunct Professor, Speech & Hearing Sciences |
| Larry N. Thibos, Ph.D. | Associate Professor, Visual Sciences |
| James T. Townsend, Ph.D. | Ph.D. Rudy Professor, Psychology and Cognitive Science |

Associate Investigators

| | |
|---|---|
| Geoffrey P. Bingham, Ph.D. | Assistant Professor, Psychology and Cognitive Science |
| N. John Castellan, Jr., Ph.D. | Professor, Psychology and Cognitive Science |
| Michael Gasser, Ph.D. | Assistant Professor, Computer Science and Cognitive Science |
| Diane Kewley-Port, Ph.D. | Associate Professor, Speech &Hearing Sciences |
| Gary R. Kidd, Ph.D. | Associate Scientist, Speech & Hearing Sciences |

| | |
|---|---|
| Daniel P. Maki, Ph.D. | Professor, Mathematics |
| Roderick Suthers, Ph.D. | Professor, Medical Sciences |

Visiting Investigators

| | | |
|---|---|---|
| Paul M. Evans, Ph.D. | Willamette University | Tactile Laboratory & Multi-Modality Laboratory |
| Andrew Dillon | HUSAT Research Institute Loughborough, England | Human Factors |

The following personnel contributed to research projects described in this report. Those entirely or partially supported by the Institute are identified by asterisks.

Research collaborators

| | | |
|---|---|---|
| G.D. Abbott | CREARE, Inc. , New Hampshire | Research Scientist |
| A.A. Atchison | Queensland University of Technology | School of Optometry |
| J. R. Busemeyer | Purdue University Psychological Sciences | Associate Professor |
| S. Clark | University of California, Riverside | Associate Professor |
| M. J. Collins | Queensland University of Technology | School of Optometry |
| W. Jaestaedt | Creighton Univ. School of Medicine: | Professor of Human Communications |
| | Boy's Town National Research Hospital: | Director of Research |
| A. Rahman | Indiana University | M.S. |
| Serita Soni | Indiana University | O.D., M.S. |
| William Stampfli | Indiana University | Professor of Mathematics |
| Janet Weisenberger | Ohio Univ. Dept. of Speech and Hearing | Associate Professor |

Research Programmers

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|---|---|---|
| Wancheng Wang | B.S. | Psychology |
| John A. McLain | | Hearing & Communications |

Research Associates

| | | |
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| *Sheldon Li | Ph.D. | Hearing & Communication |
| Michael Muchisky | Ph.D. | Visual Sciences |
| Jennifer Romack | Ph.D. | Visual Sciences |
| *Xiaoxiao Zhang | Ph.D. | Visual Sciences |

Research Assistants

| Name | Degree | Laboratory |
|---|---|---|
| Sven Anderson | M.A. | Phonetics |
| Douglas Blank | M.S. | Connectionist Models |
| R.A. Buss | M.S. | Psychology |

| | | |
|---|---|---|
| Laurel Christopherson | M.A. | Audiology |
| Carol Cokely | M.A. | Audiology |
| Czerwinski, Mary | M.A. | Psychology |
| Frederic Cummins | M.S. | Linguistics |
| Catharina De Jonge | M.S. | Linguistics |
| Ward Drennan | M.S. | Hearing & Communications |
| Michael Fragassi | B.A. | Mathematical Study of Human Cognition |
| David Huber | B.A. | Mathematical Study of Human Cognition |
| Leah Laurenzano | B.S. | Hearing & Communications |
| M.M. Muchisky | M.S. | Psychology |
| Nancy Lightfoot | B.A. | Mathematical Study of Human Cognition |
| *Kimberly Marinelli | B.A. | Mathematical Study of Human Cognition |
| Devin McAuley | M.S. | Connectionist Models |
| Lisa Meeden | M.S. | Connectionist Models |
| Jaun Pablo Mora | M.S. | Linguistics |
| *Armona Nadler | B.A. | Audiology |
| Peter Nobel | B.S. | Mathematical Study of Human Cognition |
| Jill Peters | M.S. | Auditory Perception |
| Petersime, Tim | M.S. | Psychology |
| Martin Rickert | M.S. | Auditory Research |
| Martha Rinker | B.S. | Tactile Perception |
| Catherine L. Rogers | B.A. | Linguistics |
| Jennifer Romack | M.S. | Health, Physical Education and Recreation |
| Eric Rosenwinkel | B.A. | Mathematical Study of Human Cognition |
| *Maurice Rynders | M.S. | Visual Sciences |
| *Robin Thomas | B.S. | Mathematical Study of Human Cognition |
| Michael Wilkinson | M.S. | Visual Sciences |
| *Ming Ye | B.S. | Visual Sciences |
| Heidi Zeimer | B.A. | Mathematical Study of Human Cognition |

Technicians

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|---|---|---|
| Mike Bailey | | Auditory Research |
| Jerry C. Forshee | M.S. | Auditory Research |
| *Kevin Haggerty | B.A. | Visual Sciences |
| *David Link | | Auditory Research |
| *John A. McLain | | Hearing & Communications |
| *David Montgomery | ASEET | Hearing & Communications |
| *Roger P. Rhodes | B.S. | Tactile Perception |

Administrative Assistants

| | | |
|---|---|---|
| Ada Simmons | B.S. | Institute for the Study of Human Capabilities |
| Carol Rhodes | B.A. | |

# Introduction

This Annual Technical Report of AFOSR grant #90-0215, which funds the Institute for the Study of Human Capabilities, describes work in several areas, all of which focus on problems of skilled human performance. The Institute's investigators are primarily active in the fields of sensory processes including vision, audition, and touch, and in human cognition and decision making; research in those areas represent the major content of this report.

Specific projects continue to focus on human subjects' abilities to use information obtained from visual, auditory, and tactile displays. Both empirical and theoretical studies continue to be conducted. Studies of human cognition include a continuing study of optimal strategies for machine-aided detection and recognition, the integration of information from multiple observations, automatization of perceptual processes, and automatization as a mechanism for overcoming attentional limitations.

*Research Support.* The research projects described in this report have been supported either partially or completely by the URI/AFOSR grant to the Institute for the Study of Human Capabilities. It is emphasized, however, that the majority of the investigators also receive project support from other agencies, as listed on pages 36 to 38 of this report. Institute funding, while a small portion of the total research support of the 13 affiliated laboratories, is a primary reason for the interdisciplinary cooperation that has developed among its member scientists, during the past seven years. Institute funds have been used, roughly in order of amounts expended to:

(a) support graduate-student research assistants working on Institute-proposed projects;

(b) provide supplementary technical assistance for equipment design, maintenance, and computer program development;

(c) maintain and enhance apparatus for cross-modality investigations;

(d) support short- and long-term visits to the Institute by scientists interested in application of basic research to human engineering problems;

(e) support a one-half time secretary-administrator, and one-third summer salary for the Institute director, C.S. Watson; and

(f) support travel to scientific meetings for the purpose of reporting Institute-supported research.

*Areas of Research.* Current research projects in Institute-affiliated laboratories include studies in the following categories:

I. Auditory Discrimination: the psychophysics of auditory capabilities, the limits of auditory attentional capacity, the ability to discriminate signals composed of gaussian noise samples.

II. Multi-Modality Testing: research in temporal resolution of multi-sensory cues, an adaptive protocol for estimating cross-modal temporal resolution, and cross-modal equivalence.

III. Tactile Discrimination: development of tactile arrays, and studies of interference in tactile localization.

IV. Visual Discrimination: human peripheral vision, human visual optics, spatial processing of color information, perception of moving objects, and color theory.

V. Cognition and Decision Making: multi-stage decision making, perception of multidimensional complex sounds, differences between visual and memory search, connectionist models for auditory and speech perception, use of fault trees, and computer-based instruction.

VI. Connectionist Models of Sensory and Cognitive Processes: development and testing of neural networks for identification of polysyllabic words and tonal sequences.

VII. New research in the Speech Research Laboratory: speech analysis, synthesis and perception, including word recognition and lexical access.

*Form and Content of the Reports.* It is not our intention to provide sufficient information in the brief project descriptions included here so that any of this work could be replicated. We believe such detail is best reserved for the descriptions of the work that will be submitted to appropriate journals, and specifically discourage any citation of reports which, like these, have not been through the scrutiny of independent peer review. We do hope, however, that the early knowledge of research that is underway or that, because of publication lags, will not appear for some time in the open literature, may be of value to colleagues who are working in closely related areas. We encourage readers of these brief reports to write to individual investigators if further detail is desired on any of the projects. In some instances draft manuscripts are available, and we will do our best to provide whatever information is requested.

*New Projects and Personnel.* New projects have been begun during the past year in most of the Institute-affiliated laboratories, as described in later sections of this report. Richard Shiffrin has served as Associate Director of the Institute during this past year and his cooperation has been especially valuable because he also serves as Director of the University's Cognitive Science program. It seems clear that the applied field of human factors, if it is to move ahead with the rest of the scientific community, will need to adapt to (and benefit from) the "cognitive revolution." Larry Thibos, from the Department of Visual Science, served as Acting Director during the fall semester (September - December, 1991) during which time C.S. Watson was on a combined sabbatical and research leave at the Applied Psychology unit of the Medical Research Council, Cambridge, England. Watson devoted a portion of that semester to visits to applied research organizations in the U.K.

In June, 1992, Ada Simmons, who served as a very capable administrative assistant/office manager/grants accountant/editor and purchasing agent for the Institute, left for a position in University administration. We were fortunate to locate an excellent person to succeed Ada, Carol Rhodes. Carol's previous experience includes the administration of externally-funded research in the Department of Visual Sciences at I.U.

In 1991-92, work was completed on the rehabilitation of three small research buildings for Institute projects. Two of these , an anechoic and an echoic chamber, were originally part of J.P. Egan's laboratory at IU, but which had been used as storage buildings for the past 10-15 years. The other is a small residence that has been refurbished as a multi-station human-subjects testing facility for use in Human Factors research.

*Institute-sponsored Symposium.* The Institute organized a third symposium held on March 25-27, 1992, on the topic of "Human Error." The conference co-chair was Neville Moray, from the University of Illinois. The purpose of the conference was to review the relation of recent advances in basic research to major applied problems in the field of human engineering. The speakers included members of the Institute and several investigators from other organizations whose work combines basic and applied research in the field of human perception, cognition, or decision making. Among the speakers from outside the University were several national leaders in applied research, including Moray, Barry Kantowitz (Batteile Human Affairs Research Center, Seattle), Raja Parasuraman (Catholic University of America, Washington, D.C.), and Colin Drury (SUNY, Buffalo). Two Speakers from the U.K. were Andrew Dillon, the Institute's visiting scientist from HUSAT, Loughborough University, and James Reason, from the University of Manchester. This symposium provided an excellent overview of the practical demands being made on the human-oriented sciences.

*Reprints.* The bibliography at the end of this report lists articles by members of our research groups that have appeared over the past four years.

The design, conduct, and interpretation of experiments in these reports typically reflects the joint intellectual efforts of investigators, research assistants, and many others who participate in the research projects. While we try to give credit where it is due, the ownership of initial ideas is often impossible to establish. We are only certain of who does the work involved in the collection and analyses of data, and who writes the final papers; those persons are formally recognized through authorship, but often a "group as a whole" is as close as we can come to the source of the original ideas for an experiment or for forms of analysis or, most importantly, for a theory. It is a pleasure, at any rate, to work with colleagues who seem to have an inexhaustible reserve of new ways to think about interesting problems.

CSW

# I. Auditory Discrimination

*The proportion-of-the-total-duration (PTD) rule for auditory pattern discrimination.*
Kidd, Watson

A paper describing our discovery of the PTD rule has been accepted for publication. The experiments described in the published paper demonstrate that, for a wide range of conditions, frequency resolving power for each individual component of an unfamiliar sequence of tones increases with the component's proportion of the total sequence duration. This work has now been extended to the case of duration discrimination. Listeners were asked to detect a change in the duration of a single tone in a five-tone pattern using a modified two-alternative forced choice procedure (S/2AFC). The sequence of durations in each pattern was randomly determined on each trial (with the constraints of a minimum duration of 20 msec and a minimum difference between durations of 5 msec). The experiment included both positive and negative duration changes in fast (250 msec) and slow (750 msec) patterns. One simple frequency pattern, a sequence of ascending frequencies, was used throughout the experiment. The pattern of results obtained was essentially the same as that found in the frequency-discrimination experiments. As the proportion of the total pattern duration occupied by the target tone decreased from 0.40 to 0.10, duration discrimination thresholds (t/t) increased tenfold (roughly from 0.04 to 0.4 for mean thresholds computed over all conditions). Thus, increases in a component's proportional duration facilitate the discrimination of duration changes as well as frequency changes. This finding supports the view that increases in a components' PTD lead to increased perceptual salience, which results in greater resolving power for all of the component's properties.

Manuscripts and Abstracts

Kidd, G. R., & Watson, C. S. The "proportion-of-the-total-duration (PTD) rule" for the discrimination of auditory patterns. *Journal of the Acoustical Society of America,* (accepted January 1992).

*The effect of position uncertainty on frequency discrimination with well-learned patterns.*
Kidd, Watson, Drennan

Several earlier experiments have demonstrated large improvements in the discriminability of changes in a single "target" tone in a multi-tone sequence as pattern uncertainty (defined in terms of the number of different patterns used in an experiment) is reduced. A new experiment has been conducted to test the effect of variation in position uncertainty (i.e., uncertainty with respect to the serial position of a target tone) when the same pattern is presented on every trial. The goal was to determine the degree to which knowledge of the serial position of the target tone can facilitate discrimination of target-tone changes in well-learned sequences. Frequency-discrimination thresholds were determined for each component of a single ten-tone pattern (using multiple adaptive tracks in a S/2AFC paradigm) after several days of training under position uncertainty. Following this training, discrimination thresholds for four of the components were tested under minimal uncertainty. The target position was held constant over trials for several testing sessions. The results showed only a slight improvement , indicating that position uncertainty is not a major factor in discrimination, once a pattern is well-learned.

*Targeting attention to specific spectral-temporal locations in patterns of tones.*
Kidd

This experiment was designed to provide a measure of the changes in detection thresholds for tones at unexpected temporal locations, for varying degrees of deviation from an expected temporal location. Four listeners were tested using an adaptive-tracking procedure designed to estimate detection thresholds for single tones within randomly-generated sequences of tones. Temporal expectancies were established by repeated presentation, over trials, of an isochronous pattern. A modified 2AFC procedure was used in which a standard pattern was repeated four times, followed by two comparison patterns. One of the comparison patterns included a temporally displaced target tone at an intensity level equal to or less than the other tones in the pattern; the other comparison pattern had a silent interval in place of the target tone. Listeners judged which comparison pattern contained a silent gap in place of a tone. They were told that the pattern without the silent gap may include a temporal change and a decrease in level but that it will always have the same sequence of tones. Three amounts of positive deviation (i.e., later-than-expected onset) and three amounts of negative deviation (i.e., earlier-than-expected onset) were included. Patterns were presented at either a fast (50-ms tones with 50-ms inter-tone intervals) or a slow (50-ms tones with 150-ms inter-tone intervals) rate of presentation. Temporal deviations occurred at serial position 5 or 10 in the 12-tone sequences. Listeners were tested for 90 minutes every weekday for six weeks. Thresholds for detection of temporally displaced tones were determined by adaptive tracking. Detection thresholds were found to increase with increases in the amount of deviation from the expected temporal location for both pattern positions at both rates. The listeners were quite good at detecting the attenuated target tones, with mean thresholds for the group of four listeners ranging from 60 to 67 dB (SPL) below the 75 dB non-target tones. The effect of temporal deviation tended to be greatest for tones at position 5 in the fast patterns, and weakest for tones at position 10 in the slow patterns. Overall, the threshold shift with increases in the amount of deviation was relatively small, with mean threshold shifts ranging from 2 to 5 dB. However, this was after considerable practice with temporal deviations, and listeners may very well have developed attentional strategies that diminished the effect.

## Presentations

Watson, C. S., & Kidd, G. R. (1992). Psychoacoustics and psychophysics of auditory warnings and displays. Presented at the Conference on Human Error, Indiana University, Bloomington, Indiana, March 1992.

Watson, C. S., Kidd, G. R., & Foyle, D. (1991). The proportion-of-the-total-duration (PTD) rule for auditory pattern discrimination. Presented at the *Third Annual Convention of the American Psychological Society.*, Washington, D.C., June 1991.

## Manuscripts and Abstracts

Kidd, G. R., & Watson, C. S. The "proportion-of-the-total-duration (PTD) rule" for the discrimination of auditory patterns. *Journal of the Acoustical Society of America,* (accepted January 1992).

Kidd, G. R., & Watson, C. S. (1991). Dimension-specific processing capacity for auditory patterns. *Journal of the Acoustical Society of America*, **90**, Pt. 2, S2267.

*Additivity of Auditory Masking*
Humes, Cokely, Lee, Jesteadt & Halling

We continue to explore the additivity of masking in normal-hearing listeners. Issues investigated include the influence of spectral and/or temporal overlap of the maskers with each other or with the signal. Results to date indicate that the linear power-summation of masking is the exception rather than the rule and is restricted to the special case of temporal AND spectral overlap of both maskers.

*Identification of Multidimensional Auditory Stimuli*
Humes, Christopherson, Nosofsky

Experiments are being conducted on normal-hearing listeners' ability to identify artificial acoustic stimuli having stimulus characteristics that vary along three independent dimensions. In one experiment, stimuli had one of two values of temporal onset (abrupt/gradual), harmonicity of components (harmonic/inharmonic), and spectral envelope (smooth/peaked). Stimulus values along each dimension were simultaneously presented (parallel) in 100-ms tokens. Subjects identification performance was consistent with their identification on the basis of one preferred stimulus dimension, with different subjects preferring different dimensions. With training, subjects could learn to focus their attention on previously nonpreferred dimensions. Extension of these initial results to stimuli with three new dimensions (spectral location of noise, duration of temporal gap, extent of frequency transition) presented sequentially (series) is being examined. Eventually, this work will be extended to hearing-impaired elderly listeners to examine their ability to learn to use new cues to identify complex multidimensional stimuli.

# II. Multi-Modality Testing

*Correlations between auditory and visual speech processing ability: evidence for an modality-independent source of variance.*
Watson, Qiu, Chamberlain

Two experiments were run to determine whether the individual differences in auditory speech processing are predictable from those in speechreading, using a total of 90 normal-hearing subjects. Tests included single words and sentences. The speech was recorded on a video disk by a male actor (Bernstein and Eberhardt, 1986), Johns Hopkins Lipreading Corpus. The auditory speech was presented with a white noise masker, at -7 dB Sp/N. The correlations between overall auditory and visual performance were 0.52 and 0.45, in the two studies, suggesting the existence of a modality-independent ability to perceive linguistic "wholes" on the basis of linguistic fragments. Subjects also identified printed sentences with 40-60% of the portions of the letters deleted. Performance on the "visual-fragments" test also correlated significantly with visual and auditory speech processing.

Manuscripts and Abstracts

Watson, C.S., Qiu, W.W., and Chamberlain, M. (1992) Correlations between auditory and visual speech processing ability: evidence for a modality-independent source of variance. *J. Acoust. Soc. Am.* **92**, Suppl. 1.

# III. Tactile Discrimination

*Tactile attention.*
Evans, Craig, Rinker

Previous studies in the laboratory showed that subjects had difficulty attending to a particular location on the skin and ignoring stimuli presented to adjacent locations. Specifically, subjects were required to identify a stimulus, typically a pattern moving across a fingerpad in a particular direction, and to ignore a moving pattern presented to an adjacent fingerpad. Using a paradigm similar to that used in visual studies of attention (four stimuli signalling two responses), it was determined that the interfering effect of nontarget stimuli primarily results from the nontarget signalling a different response, rather than interference (masking) at some relatively early stage of processing.

Using this four stimuli, two response paradigm, we investigated the effect of distance on the amount of interference. With visual stimuli, it has been shown that within a small area around a target stimulus increasing the spatial separation between the target and nontargets has no effect on interference. Beyond about 1 degree of visual angle, though, increasing distance results in a decrease in interference. These results have led to a "spotlight" of attention for visual stimuli. To test the appropriateness of this model for the skin, we presented nontarget stimuli to fingerpads that were adjacent to (near) the target site or the fingerpads that were nonadjacent (far). The results showed an equally large response-competition effect independent of the distance between target and nontarget. The results indicated that the focus of attention extends nearly undiminished across the fingers of one hand.

With the same paradigm, we moved the nontarget stimuli to the opposite hand. Unlike the results obtained with a simpler paradigm, we found an interference effect even when the target and nontarget stimuli were presented to opposite hands; however, the effect was diminished relative to that seen with stimuli presented to the same hand. Also, the size of the bilateral interference effect remained the same whether the two hands were placed next to one another or 25 cm apart.

Presentations:

Evans, P.M. and Craig, J.C. Presented to the Psychonomic Society, San Francisco, CA, November, 1991.

Manuscripts and Abstracts:

Evans, P.M. and Craig, J.C. (1992). Response competition: A major source of interference in a tactile identification task. *Perception & Psychophysics*, **51**, 199-206.

Rinker, M.A. Spatial and temporal factors of tactile attention. Unpublished first year project, Indiana University, 1991.

Evans, P.M., Craig, J.C., and Rinker, M.A. (In press). Perceptual processing of adjacent and nonadjacent tactile nontargets. *Perception & Psychophysics.*

*Tactile speech.*
Weisenberger, Craig, Abbott

This study evaluated a tactile speech aid. Using a principal component analysis, speech information was presented on a two-dimensional array of vibrators brought in contact with the subject's skin. Reasonably good levels of performance on several speech tasks, including lipreading, indicated that principal component design is a promising alternative to tactile vocoders.

## Manuscripts and Abstracts

Weisenberger, J.M., Craig, J.C., and Abbott, G.D. (1991). Evaluation of a principal-components tactile aid for the hearing-impaired. *Journal of the Acoustical Society of America,* **90,** 1944-1957.

# IV. Visual Discrimination

## A. Human Vision

Manuscripts and Abstracts

*Spatial vision.*

Applegate, R.A., Bradley, A. and Thibos, L. N. (1991) Visual Acuity and pupil size in maxwellian and free view systems with and without refractive error. *Optical Society of America Digest for the 1992 Non-invasive Assessment of the Visual System Topical Meeting*, series vol 1, pp 170-174.

Bradley, A., Thibos, L. N., Wang, Y., Haggerty, K., and Poorman, A. (1992) Imaging FWC. *Opthal. Physiol.Op.* (in press).

*Chromostereopsis.*

Ye, M., Bradley, A., Thibos, L.N., and Zhang, X. (1991). Interocular differences in transverse chromatic aberration determine chromostereopsis for small pupils. *Vision Res.* **31**, 1787-1796.

Ye., M., Bradley, A., Zhang, X. and Thibos, L.N. (1992). Effects of chromatic aberrations and the Stiles-Crawford effect on chromostereopsis. *Vis. Res.* (in press).

*Color vision.*

Bradley, A. Zhang, X. X. and Thibos, L. N. (1992). Failures of isoluminance caused by ocular chromatic aberrations. *Applied Optics* (in press).

*Studies of Monocular diplopia*
Bradley, Rahman, Zhang, Ye,Thibos

With the advent of widely-used contact lens corrections for most types of ametropia, we now have an aging population of ametropes unaccustomed to wearing spectacles. The onset of presbyopia in this population has posed new challenges for the eye care community. The presbyope has the option of relinquishing their contact lenses and adopting the more traditional spectacle lens corrections for presbyopes. The design principle of a bifocal spectacle lens allows the entering ray bundle to pass through different portions of the lens each with a different optical power. One area of the lens corrects distance vision and one near vision. By adjusting his or her gaze, the patient is able to select the region, and hence the optical power, of choice. Such manipulation of effective optical correction by changing direction of gaze is not possible with a contact lens. In order to provide a "bifocal" correction with a contact lens, part of the ray bundle entering the eye is corrected for distance and part for near. That is, at all times, part of the ray bundle will be out of focus. These lenses simultaneously create two rather than one image (simultaneous vision bifocals). We are studying the impact of this monocular diplopia on visual performance.

Manuscripts and Abstracts

Atchison, A. A., Ye, M., Bradley, A., Collins, M. J., Zhang, X., Thibos, L. N. and Rahman, A. (1992) Chromatic aberration and optical power of a diffraction bifocal contact lens. (in press, *Optom. Vis. Sci..)*

Rahman, H. A., Bradley, A., Soni. S. and Zhang, X. (1992) Letter contrast sensitivity with simultaneous vision bifocal contact lenses. *Optom. Vis. Sci.* (submitted).

Zhang, X., Bradley, A., Ye, M. and Thibos, L. N. (1991) An experimental model of bifocal vision. *Optical Society of America Digest for the 1992 Opthalmic and Visual Optics Meeting,* Series vol. 3, pp 102-105.

Bradley A., Rahman, A., Soni, P.S. and Zhang, X., (1991) Through-focus measures of vision with 2-zone and diffractive bifocal contact lenses. *American Academy of Optometry Symposium on Simultaneous Bifocal and Multifocal Vision.*

Bradley, A., (1992) Hi-tech bifocal contact lenses: a marriage of holography and vanity creates a human factors nightmare. Human Error Conference, Indiana University.

**B. Human Factors and Applied (Clinical) Research**

Manuscripts and Abstracts

*Entopic visualization of retinal vascular detail.*

Bradley, A. (1991). Noninvasive assessment of the visual system. *Optics and Photonics*, **2**, 50.

Bradley, A., Applegate, R. A. Zeffren, B., and van Heuven, W. A. J. (1991). Psychophysical determination of the size and shape of the human foveal avascular zone. *Opthal. Physiol. Op.*, **12**, 18-23.

Bradley, A. and Applegate, R. A. (1991). Clinical value of the vascular entoptoscope. Presented at the Fergus Fest in Cambridge, England.

*Evaluation of clinical tests of contrast sensitivity.*

Bradley, A., Hook, J., and Haeseker, J. (1991). A comparison of clinical acuity and contrast sensitivity charts: Effect of uncorrrected myopia. *Opthal. Physiol. Op.*, **11**, 218-226.

Bradley, A., Huerres, M. Kalaher, M., and Thomas (1991). Effects of spherical and astigmatic defocus on acuity and contrast sensitivity: A comparison of three clinical charts. *Optom. Vis. Sci.*, **68**, 418-426.

## C. Human Visual Optics

Manuscripts and Abstracts

*Measurement of ocular chromatic aberration.*

Thibos, L. N., Bradley, A. (1991). Fun with interferometers. Presented at the Fergus Fest in Cambridge, England. *Opthal. Physiol. Op.*.

Thibos, L. N. Bradley,. A. and Zhang, X. X. (1991). The effect of ocular chromatic aberration on monocular visual performance. *Optom. Vis. Sci.* **68**, 456-458.

Zhang, x., Thibos, L. N., and Bradley, A. (1991). A simple model to describe the relationship between the chromatic difference of focus and chromatic difference of magnification in human eyes. *Optom. Vis. Sci.*, **68**, 456-458.

Zhang, X., Bradley, A., and Thibos, L. N. (1992). Experimental measurements of ocular chromatic difference of magnification and the anterior nodal point. *Opt. Soc. Am.* (submitted).

*Optical correction of chromatic aberration.*

Zhang, X., Bradley, A., and Thibos, L. N. (1991). Achromatizing the human eye: the problem of chromatic parallax. *J. Opt. Soc. Am.*, **8**, 686-691.

Bradley, Zhang, X., and Thibos, L. N. (1991). Achromatizing the human eye. *Optom. Vis. Sci.*, **68**, 608-616.

Bradley, A. (1992). Glen Fry Award Lecture: Perceptual manifestations of imperfect optics in the human eye: Attempts to correct for ocular chromatic aberration. *Optom. Vis. Sci.* (in press).

*Retinal image quality and visual performance.*

Thibos, L. N., Bradley, A., and Still, D. (1991). Interferometric measurement of visual acuity and the effect of ocular chromatic aberration. *Appl. Opt.* **30**, 2079-2087.

Bradley, A. (1991). Perceptual manifestations of imperfect optics in the human eye: entopic tools for studying retinal image quality. Glenn Fry Award Lecture presented to the *Am. Acad. Optom.* Annual Meeting.

Bradley, A., Thibos, L. N., Zhang, X., and Ye, M. (1991). The effects of ocular chromatic aberration of visual performance for displayed achromatic and chromatic information. *Society for Information Display International Symposium Digest of Technical Papers*, pp. 304-307.

Zhang, X., Thibos, A., Bradley and Ye, M. (1991). Modelling effects of defocus on human eyes with large pupils. *Invest. Opthal. Vis. Sci.*, **32**, Suppl. 1211.

Bradley, A., and Thibos, L. N. (1991). Incorporating the eye's optics into an applied model of detection and identifiacation of objects: Presented to the *Armstrong Laboratory Advisory Group Conference* in San Antonio, TX.

*Color-contrast modulation transfer functions and the effect of ocular chromatic aberration.*

Thibos. L. N., Zhang, X., Bradley, A., and Ye, M. (1991). Color contrast modulation transfer functions and the effect of ocular chromatic aberration. *Invest. Opth. Vis. Sci.*, **32**, (Suppl.) 1210.

*Neural basis of scotopic acuity.*

Wilkinson, M., Thibos, L. N., and Bradley, A. (1991). Neural basis of scotopic acuity. *Invest. Opth. Vis. Sci.*, **32**, (Suppl.) 699.

*The chromatic eye: A new model of ocular chromatic aberration.*

Thibos, L. N., Ye, M., Zhang, X., and Bradley, A. (1991). The chromatic eye: A new model of ocular chromatic aberration. *Opt. Soc. Am Digest: Topical Meeting on Opthalmic and Visual Optics*, **2**, 16-19.

Thibos, L. N., Ye, M., Zhang, X. and Bradley, A. (1991). The Chromatic Eye: A new reduced-eye model of ocular chromatic aberration in humans. *Applied Optics* (in press).

*Psychophysical determination of the factors limiting human peripheral vision.*
Thibos, Wilkinson, Anderson, Bradley

Unlike foveal (central) vision, peripheral vision lacks fine resolution of spatial detail, sensitive color discrimination, and generally seems to provide inferior perception. The most striking difference between central and peripheral vision is the large disparity in the neural representation of the retinal image. There are fewer receptor, ganglion cell, and cortical cells processing any given area of the retinal periphery than a similar-sized area in the fovea. Interestingly, the optical quality of the peripheral image is almost as good as that seen in the fovea. We have been examining the consequences of the reduction in number of neurons processing the peripheral retinal images.

Manuscripts and Abstracts

Anderson, R., Wang, Y., and Thibos, L. N. (1992). Factors affecting letter discrimination in the fovea and periphery. *Invest. Opthal. Vis. Sci.* (Suppl.) **33**, p. 1344.

Thibos, L. N. and Bradley, A. (1992). New methodologies for discriminating neural and optical losses of vision. *Optometry and Vision Science* (in press).

Thibos, L. N. and Bradley, A. (1991). Optical and retinal limits to central and peripheral vision. *Society for Information Display International Symposium Digest of Technical Papers*, pp. 308-310.

**D. Event Perception**

Manuscripts and Abstracts

*Visual perception of lifted weight.*

Bingham, G.P. (1992). Scaling judgments of lifted weight: Lifter size and the role of the standard. Research Report #72, *Cognitive Science Reports Series*, Indiana University. Submitted for publication.

*Perceiving the size of objects in events*
Bingham

Traditional solutions to the problem of size perception have confounded size and distance perception. We investigated size perception using information that is independent of distance. As do the shapes of biological objects (Bingham, 1992), the forms of events vary with size. We investigated whether observers were able to use size specific variations in the kinematic forms of events as information about size. Observers judged the size of a ball in displays containing only kinematic information about size. This was accomplished by covarying object distance and actual size to produce equivalent image sizes for all objects and extents in the displays. Simulations were generated using dynamical models for planar events. Motions were confined to a plane parallel to the display screen. Mass density, friction, and elasticity were held constant over changes in size, simulating wooden balls. Observers were able to detect increasing size of the ball. Mean judgments exhibited a pattern predicted by a scaling factor in the equation of motion derived using similarity analysis.

Presentations

Bingham, G.P. & Muchisky, M.M. (1991). Size perception in events. Presented at a meeting of the *International Society for Ecological Psychology* at Trinity College, Hartford, CT, October 19th.

Bingham, G.P. & Muchisky, M.M. (1992). Perceiving size in events. Presented at the Department of Psychology, Indiana University, Bloomington, IN, April 1st.

Manuscripts and Abstracts

Muchisky, M.M. & Bingham, G.P. (1992). Size perception in events. *ISEP Newletter*

Muchisky, M.M. & Bingham, G.P. (1992). Perceiving size in events via kinematic form. *Proceedings of the 14th Annual Conference of the Cognitive Science Society.* Forthcoming.

*Visual perception of tree size.*
Bingham

Two aspects of the shape of trees are constrained by scaling laws that produce a relation between tree size and tree shape. We have been investigating tree shape as information about tree size by producing tree silhouettes via computer graphics simulations that have been borrowed from research in tree morphology and that model the physical processes underlying the relevant scaling laws. Observers have been asked to judge tree height merely from the silhouettes, all of the same image size and without any background structure. Results compare favorably with results when the same observers were asked to judge the height of real trees observed around the campus. We next placed the tree silhouettes in the context of a ground texture gradient together with a set of cylinders of varying size placed at various locations within the gradient. The problem with either ground texture gradients or motion parallax fields is that neither provide information for absolute scale. Only the relative sizes and distances of objects within the field can be determined. We investigated whether the trees might confer an absolute scale on a ground texture gradient. This possibility was confirmed by our results. Observers were able to estimate the size of the cylinders when they appeared in the context of the trees, but not without the trees.

## Presentations

Bingham, G.P. & Gutjahr, E.C. (1990). Perceiving the size of trees: An inkling of a solution to the scaling problem in event perception. An invited paper presented at a meeting of the *Midwestern Psychological Association* in Chicago, Il, May 4th.

Bingham, G.P. & Gutjahr, E.C. (1990). Perceiving the size of trees: Reducing the problem of size perception to a problem of form perception. A paper presented at a meeting of the *International Society for Ecological Psychology* at the Beckman Institute, University of Illinois, Urbana, Il, May 22nd.

Bingham, G.P. (1992). Perceiving the size of trees via their form. Presented at the Department of Psychology, Indiana University, Bloomington, IN, April 15th.

Bingham, G.P. (1992). Perceiving the size of biological objects: Form as information for scale. A paper presented at a meeting of the *Association for Research in Vision and Ophthalmology*, Sarasota Springs, Florida, May 5th.

## Manuscripts and Abstracts

Bingham, G. P. (1992). Perceiving the size of trees via their form. *Proceedings of the 14th Annual Conference of the Cognitive Science Society.* Forthcoming.

Bingham, G.P. (1992). Form as information about scale: Perceiving the size of trees. Submitted for publication.

*Visual identification of events*
Bingham

People are able to perceive and recognize events. How might event structure and corresponding information about events be described? We have developed 'optical phase space' as a possible description and as a way to illustrate both the nature of events as objects of perception and the problem of mapping from event structure to optics. Optical phase space yields enough structure to allow us to analyze the identification of such dynamical properties as rigidity, elasticity, plasticity, and liquid flow. The importance of event dynamics in determining the perceptual significance of motions in events was investigated. Patch-light displays were recorded for 9 simple events selected to represent different kinds of dynamics including rigid body dynamics, biodynamics, hydrodynamics, and aerodynamics. Observers of the displays described the events in both a free response task and in tasks in which observers circled properties in a list. Results of cluster analyses performed on frequencies for descriptors reflected the underlying dynamics rather than crude kinematic similarities among the displays. Observers discriminated animate versus inanimate versions of rigid body events where only the form of the phase trajectories differed. Three viewing conditions were used as a between-subjects manipulation including upright displays and observers, inverted displays and upright observers, and upright displays and inverted observers. Perceived event identities varied with the absolute orientation of the displays with respect to gravity, but were unaffected by the relative orientation of display and observer. Finally, the event kinematics were measured and investigated as the source of information for event identities. A force-choice task confirmed the ability to discriminate animate motions based only on the form of phase space trajectories. The dynamics of these events was modeled to discover the properties which revealed animate activity.

Presentations

Bingham, G.P. (1991). The identification problem in visual event perception. Presented at a *Conference on Dynamic Representation in Cognition,* Indiana University, Bloomington, IN, November 16th.

Manuscripts and Abstracts

Bingham, G.P. (1991). The identification problem in visual event perception. Part I. Rate structures in optic flow and the degrees of freedom problem. Research Report #52, *Cognitive Science Reports Series,* Indiana University.

Bingham, G.P. . Rosenblum, L.D. & Schmidt, R.C. (1991). The identification problem in visual event perception. Part II. Dynamics and orientation. Research Report #53, *Cognitive Science Reports Series,* Indiana University.

**E. Perception/Action**

*Optic flow generated by eye movements.*

Presentations

Bingham, G.P. (1991). Detection of accretion/deletion of optical texture at occluding edges produced by eye movement with head immobilized. Presented at a meeting of the *Association for*

*Research in Vision and Ophthalmology*, Sarasota Springs, Florida, April 30th.

Bingham, G.P. (1991). Detection of accretion/deletion of optical texture at occluding edges produced by eye movement with head immobilized. Presented at the 6th *International Conference on Event Perception and Action*, Amsterdam, August 30th.

Bingham, G.P. (1991). Why does optical pattern never look flat? (Or the demise of 'efference copy'). Presented at the Department of Psychology, Indiana University, Bloomington, IN, October 2nd.

Manuscripts and Abstracts

Bingham, G. P. (1991). Detection of accretion/deletion of optical texture at occluding edges produced by eye movement with head immobilized. *Investigative Ophthalmology and Visual Science*, **32**(4), 830.

Bingham, G.P. (1992). Optical flow from eye movement with head immobilized: Ocular occlusion" beyond the nose. Research Report #71, Cognitive Science Reports Series, Indiana University. Submitted for publication.

*Object shape as visual information about the center of mass.*

Presentations:

Bingham, G.P. & Muchisky, M.M. (1990). Center of mass perception. A paper presented at a meeting of the *International Society for Ecological Psychology* at the Beckman Institute, University of Illinois, Urbana, Il, May 22nd.

Bingham, G.P. & Muchisky, M.M. (1991). Center of mass perception for the visual guidance of grasping. A paper presented at the *Conference on Human Error* sponsored by the Institute for the Study of Human Capabilities at Indiana University, March 22nd.

Bingham, G.P. & Muchisky, M.M. (1991). Center of mass perception for the visual guidance of grasping: A GSD problem. Presented at the 6th *International Conference on Event Perception and Action*, Amsterdam, August 29th.

Manuscripts and Abstracts:

Bingham, G.P. & Muchisky, M.M. (1991). Affordances and dynamics: 'Graspability' and center of mass perception. Research Report #60, *Cognitive Science Reports Series*, Indiana University. Also to appear in Flach, J.M., P. Hancock, J. Caird & K. Vicente (eds.), *The Ecology of Human-Machine Systems*. Hillsdale, N.J.: Erlbaum.

Bingham, G.P. & Muchisky, M.M. (1992). Center of mass perception and inertial frames of reference. Research Report #69, *Cognitive Science Reports Series*, Indiana University. Submitted for publication.

Bingham, G.P. & Muchisky, M.M. (1992). Center of mass perception: Perturbation of symmetry. Research Report #70, *Cognitive Science Reports Series,* Indiana University. Submitted for publication.

*Sensorimotor learning in reaching with vision through a displacement prism*
Bingham

Observers reaching to a target seen through wedge-shaped displacement prisms initially reach in the direction of displacement, correcting their reaches over a series of about 12 trials. With subsequent removal of the prisms, observers initially reach to the opposite side of the target, correcting over about 6 trials. This phenomenon has been called "adaptation" because of its similarity to the adaptation of sensory thresholds to prevailing energy levels. We show, however, that this perturbation to visually guided reaching only mimics sensory adaptation initially. Subsequent changes show that this is sensorimotor learning. Error in pointing to targets is the commonly used measure. We measured times for rapid reaches to place a stylus in a target. Participants wearing a prism worked to achieve criterion times previously established with normal, unperturbed vision. Blocks of trials with and without a prism were alternated. Both the number of trials to criterion and the mean times per block of trials decreased over successive blocks in a session, as well as over successive days. By the third day, participants were able to respond rapidly to perturbations. This reflects the acquisition of a new skill that must be similar to that acquired by users of corrective lens.

Presentations:

Bingham, G.P., Muchisky, M.M. & Romack, J. (1991). 'Adaptation' to displacement prisms is sensorimotor skill acquisition. Presented at a meeting of the *Psychonomic Society,* San Fransisco, CA, November 24th.

Bingham, G.P., Romack, J.L. & Buss, R.A. (1992). 'Adaptation' to displacement prisms is sensorimotor skill acquisition. Presented at the *Conference on Human Error* , sponsored by the Institute for the Study of Human Capabilities at Indiana University, Bloomington, IN, March 26th.

Manuscripts and Abstracts:

Romack, J.L., Buss, R.A. & Bingham, G.P. (1992). 'Adaptation' to displacement prisms is sensorimotor learning. *Proceedings of the 14th Annual Conference of the Cognitive Science Society.* Forthcoming.

**F. Color Vision**

*Model for color perception and visual adaptation.*
Guth

A schematic diagram of a model for color perception and visual adaptation has been developed by Dr. Guth with full support from the Institute. The model has been published as a major paper in the *Journal of the Optical Society of America,* and it represents an important advance in the

visual sciences. That is, given specification of a light being viewed, the model (with few exceptions) allows predictions of the light's detectability, brightness, hue, saturation, and whether or not the light will be discriminably different from other nearby lights or background fields. Furthermore, predictions can be made for vision under many adaptation conditions. Current work on the model has involved changes in the gain control (GC) equation in order to extend the model's applicability to high luminance levels.

## Manuscripts

Guth, S.L. (1991). Model for color vision and light adaptation. *J. Opt. Soc. Am. A.*, **8**, 976-993.

# V. Cognition and Decision Making

*Attention and automatism.*
Shiffrin

Nancy Lightfoot has been continuing her research into automatization (following up earlier research by a former student now at Rice and Compaq Corporation, Mary Czerwinski). Her experimental paradigm is that of visual search. The time-per-additional-displayed-item needed to find a target provides a measure of search skill and automatization (approaching zero when search is fully automatized). In research since the last progress report, search for novel characters has been studied. Such characters are gradually learned as units over 10 to 50 sessions of training, depending on their confusability. Once unitized, search improves by as much as an order of magnitude. Other results confirm previous findings concerning stages and types of automatization. A second study examines character confusability in search and attempts to predict search times on the basis of the similarity of characters in each display. This project is still ongoing. Three publications thus far have resulted from this research: Czerwinski, Lightfoot, and Shiffrin (in press), Shiffrin, Czerwinski, and Lightfoot (in press) and Lightfoot and Shiffrin (in press).

Michael Fragassi, a graduate student, and Asher Cohen, a faculty member, have collaborated on a study examining the degree to which a visual stimulus is processed during a period of time in which attention is directed to some other visual location. Eriksen and colleagues found no such processing occurred. We have shown that their result was due to the extreme confusability of the stimuli, and the short times available to process the target. In fact, we were able to demonstrate separate visual processing components, one automatic and one attentive, operating concurrently. The characters outside the focus of current attention did receive processing, albeit for fairly easy to distinguish features. We are presently preparing this research for submission.

*Memory and retrieval.*
Shiffrin

We have continued several projects examining the nature of memory storage, retrieval and forgetting. Shiffrin and Murnane (1991) summarized data showing that interference arises at retrieval rather than storage. Murnane and Shiffrin (1991) ruled out differential rehearsal as an artifactual explanation of the findings underlying this conclusion. They fit a model to the data, illustrating how sentence memory and forgetting could be accounted for with a differentiation version of a global familiarity model. Clark and Shiffrin (in press) showed how cues could act in combination and separately to govern retrieval from memory.

In new research, Kim Marinelli, Heidi Ziemer, and Dave Huber asked whether memory activation rises with changes in the number of items added to memory, or the strength of items added to memory. They used a long list of exemplars from many categories to show that activation rises with added items, but stays constant with added strength, consistent with the differentiation version of the SAM retrieval model, as shown by excellent fits of the model to data. This research is being prepared for submission.

Dave Huber carried out theoretical research exploring models of retrieval in which separate traces that become active send inhibitory signals to each other in certain circumstances. The new model is used to explain certain seemingly inexplicable findings concerning the failure of repeated items to cause forgetting. This research is continuing.

Manuscripts and Abstracts


Clark, S., & Shiffrin, R. M. (in press). Cuing effects and associative information in recognition memory. *Memory and Cognition.*

Czerwinski, M., Lightfoot, N., & Shiffrin, R. M. (in press). Automatization and training in visual search. *American Journal of Psychology.*

Lightfoot, N., & Shiffrin, R. M. (in press). On the unitization of novel, complex visual stimuli. *Proceedings of the Fourteenth Annual Conference of the Cognitive Science Society.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Murnane, K., & Shiffrin, R. M. (1991). Word repetitions in sentence recognition. *Memory & Cognition,* **19** (2), 119-130.

Shiffrin, R. M., Czerwinski, M. P., & Lightfoot, N. (in press). On the automatization of visual search. In Izawa, C. (Ed.), *Cognitive Psychology Applied.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Shiffrin, R. M., & Murnane, K. (1991). Composition, distribution, and interference in memory. Hockley, W.E., & Lewandowsky, S. (Eds.), *Relating Theory and Data: Essays on Human Memory in Honor of Bennet B. Murdock,* 331-346. Hillsdale, NJ: Lawrence Erlbaum Associates.


*Dynamic field theory of decision making.*


Busemeyer, J.R. & Townsend, J. T. (1992). Fundamental derivations from decision field theory. *Mathematical Social Sciences*, **23**, No. 3.


*General recognition theory: parallel vs. serial processing.*


Townsend, J. T. (1990). Serial vs. parallel processing: Sometimes they look like tweedledum and tweedledee but they can (and should) be distinguished. *Psychological Science*, **1**, 46-54.

Townsend, J. T. and Thomas. R. Stochastic dependencies in parallel and serial models: Effects on systems factorial interactions. Submitted for publication.

*Self-terminating vs. exhaustive processing.*

Townsend, J.T. (1992). Chaos theory: A brief tutorial and discussion. In *From Learning Processes to Cognitive Processsses: Essays in Honor of W.K. Estes*. Hillsdale, N.J.: Lawrence Erlbaum Asso.

Townsend, J.T. (1992). On the proper scales for reaction time. In H. Geissler, S. Link, and J.T. Townsend (eds.), *Cognition, Information Processing and Psychophysics: Basic Issues.* Hillsdale, N.J.: Lawrence Erlbaum Asso.

Townsend, J.T. (1990). The truth and consequences of ordinal differences in statistical distributions: Toward a theory of hierarchical inference. *Psychological Bulletin*, **108**, 551-567.

*Comments on linear models: Implications for the lens model.*

Castellan, N. J., Jr. (1992). Relations between linear models: Implications for the lens model. *Organizational Behavior and Human Decision Processes*, **51**, 364-381.

*Shuffling arrays: Appearances may be deceiving.*

Castellan, N.J., Jr. (1992). Shuffling arrays: Appearances may be deceiving. *Behavior Research Methods, Instruments, and Computers*, **24 (1)**, 72-77.

# VI. Connectionist Models of Sensory and Cognitive Processes

*A connectionist approach to the acquisition of morphophonemic rules.*
Gasser

This year work has focused on modeling the development of internal representations for phonological units, especially syllables, as a side-effect of the process of learning to recognize words. Simulations have shown that the hidden-layer patterns from networks trained on word recognition support word production and various phonological operations. Most interestingly, the approach displays robustness: presented with phone sequences not conforming to the norms of the input language, the recognition network develops representations which in effect correct the errors in the input. Future work will focus on the unsupervised learning of prosodic patterns.

*Modeling the development of the concept of sameness.*
Gasser, Smith

Recent work with the model has demonstrated the following. (1) Nominal categories develop earlier than attributes because they tend to cover a smaller area in the representational space and hence are easier to delineate. (2) A tendency for nominal categories to involve shape leads the network to develop a shape bias, as children do. (3) The categorization and comparison tasks train the network to selectively attend to linguistic dimensions, even when these do not correspond in a one-to-one fashion to input sensory dimensions.

Manuscripts and Abstracts

Lee, C.D. and Gasser, M.(1991). Where do "underlying representations" come from? A connectionist approach to the acquisition of phonological rules. In J. Dinsmore (Ed.), *Connectionist and symbolic models: Bridging the gap.* Hillsdale, NJ: Lawrence Erlbaum.

Gasser, M., & Smith, L. B. (1991). A connectionist model of the development of the notion of sameness. *Annual Conference of the Cognitive Science Society,* **13**, 719-23

Gasser, M. (1991). Learning to recognize and produce words: Towards a connectionist model. *Center for Research in Language Newsletter,* November, 1991. [not refereed]

Accepted:

Gasser, M. (1992). Learning distributed syllable representations. *Annual Conference of the Cognitive Science Society,* **14**.

Presentations

Blank, D., & Gasser, M. (1992). Grounding via scanning: Cooking up roles from scratch. *Fourth Annual Conference of the Midwest Artificial Intelligence and Cognitive Science Society.*

Gasser, M., & Celis, N. (1992). Towards a connectionist approach to transfer in machine translation. *Fourth Annual Conference of the Midwest Artificial Intelligence and Cognitive Science Society.*

Gasser, M. (March, 1992). Learning syllable representations in sequential connectionist networks. *Workshop on the Cognitive Science of Natural Language Processing,* Dublin, Ireland.

Gasser, M. (November, 1991) Phonological performance and sequential networks. Panel on Connectionism and Phonology. *Second Annual Midwest Connectfest,* Columbus, OH.

*Dynamic short-term auditory memory by connectionist models*
Port, Mcauley, Anderson, Stampfli

We are building functional models that can directly process auditory information in time. We employ recurrent networks, that is, networks with many recurrent or feedback connections. This portion of the overall project attempts to construct a memory that simulates human 'sensory trace memory' for auditory intensities in various frequency ranges. It is an extension of the model proposed by Zipser (1991). The model stores the intensity of an input tone for a period of time and gradually decays ('forgets') the tone intensity. The resulting sensitivity of the model to stimulus-onset asynchrony for a roving intensity discrimination task has been demonstrated for human listeners on a similar task (Berliner and Durlach, 1973). We are studying the dynamic behavior of this model under varying conditions of internal noise and undertaking mathematical analysis of the model as well.

Manuscripts and Abstracts

McAuley, Devin, Sven Anderson and Robert Port (1992) Sensory discrimination in a short-term dynamic memory. *Proceedings of the Cognitive Science Society* 14, Annual Meeting, 1992 (L. Erlbaum, Hillsdale, NJ), 136-140.

Port, Robert F. (1991) Can complex temporal patterns be automatized? *Behavioral and Brain Sciences,* **14**, 762-764.

Submitted for Publication

Anderson, S., and Port, Robert (1991). Evidence for syllable structure, stress and juncture from speech timing (submitted).

Port, Robert F. (1992) Review of 'Readings in Cognitive Science' by A. Collins and E. E. Smith. *Journal of Mathematical Psychology* (in press June, 1992).

Port, Robert (1991) Dynamic output is not enough. *Neural Network Review* (in press).

*Simulations of temporal pattern recognition*
Anderson, McAuley, Port, Cummins, and Stampfli

A number of additional simulations were conducted this year. The stimuli were those used in our earlier research (Port, 1990). They were tone sequences presented as 8-step-long patterns of FFT frames. In one simulation, the network was fed randomly-ordered measures in a stream and trained to recognize occurrences of the two target measures. Even with a signal/noise ratio (per individual frame) of 0 dB, the system could distinguish two target sequences from the nine other competing sequences with d' larger than 2.0. This is pretty good performance and suggests that this approach may be useful as a model of rate-invariant and noise-resistant pattern recognition.

The dynamic memory system 'listens' in a continuous fashion, without an *a priori* input window other than the sampling rate of spectral analyses. Of course, this input sampling rate also serves as the rate of internode communication within the network itself, but, unlike other models for auditory memory, the update clock of the network does not control the dynamics of the pattern recognition process. Instead, dynamic memory itself to entrain the response of the network. Apparently this system is robust enough to handle considerable natural variation in inputs. This is a step toward a continuously-functioning dynamically-controlled perceptual system for auditory patterns.

Manuscripts and Abstracts

Anderson, S., McAuley, D., and Port, R. (1991). Dynamic memory: A model for auditory pattern recognition (submitted).

*Listening experiments with tone sequences*
Kidd, Rogers, Port, Watson, Anderson, McAuley

We have conducted 3 experiments on minimal or low uncertainty tone-sequence perception. The experiments are extensions of the Speigel and Watson (1981) experiments using tone patterns that are very familiar. Subjects are given considerable training on a single tone pattern at a time and asked to discriminate changes in one tone in each pattern. In one series, we have varied the complexity of the tone pattern (with one or several changes in direction of tone sequence). It appears that the more complex the pattern, the easier it is to isolate the target tone. When patterns have few inflection points in the sequence, it is apparently more difficult to locate a particular tone (along a series of tones leading up or down) and detect a change in it. In another series, after training one tone in a pattern, we probed subjects' ability to resolve changes in both the target tone and other tones in the pattern. Our results suggest that, for the patterns we employed, when listeners know a pattern well, they are just about as good at detecting changes in non-target tones as in the target tone.

*Temporal microstructure in speech perception*
Port, Juan Pablo Mora, Catharina de Jonge

Many experiments on lexical minimal pairs have demonstrated the role of timing in the identification of words. Other work on less well controlled contexts suggests that temporal information may not be very useful for ordinary perception due to the large degree of variation from

uncontrollable contextual features. In a series of experiments using simplified speech-like non-speech stimuli whose temporal structure is based upon natural utterances, we have demonstrated that native speakers can identify words much better than nonnative listeners. Furthermore, we found to our initial surprise that a simple linear discriminant function using the vector of segment durations for a set of 30 tokens each of 3 English words was able to identify the words far better (88% correct) than native listeners (58% correct) as well as a group of Spanish speakers who speak English with a foreign accent (43% correct). There are two places to look for an explanation of this effect. The less likely possibility is that the human listeners found it impossible to optimize the combination of the durational measurements from each token. The more likely explanation, in our view, is that the human listeners are unable to simply measure the durations of the segmental intervals in these stimuli very well.

## Presentations

Mora, Juan Pablo, Robert F. Port and Catharina de Jonge (1991). 'Cross-language' word identification using durational cues only. Paper presented at the *Acoustical Society of America. Journal of the Acoustical Society of America* **90**, (A) 2253.

*Conference on dynamic representation in cognition.*
Port and van Gelder

The conference was held November 14-17, 1991, Indiana Memorial Union, Bloomington, Indiana. An important idea seems to have emerged independently in many areas of cognitive research. This is the use of dynamic models for the representation of cognitive objects. Dynamic models have been proposed for such diverse cognitive phenomena as perceptual differentiation of scents, motor control of the limbs, linguistic control of the articulatory apparatus in speech, developmental 'stages' in cognition, etc. But these models are so different as to be almost incommensurable. They share only a point of view that cognitive objects, like categories and other 'states of knowledge', are continuous and dynamic, rather than discrete and static.

Our conference, held in November, 1991 was designed to facilitate the consolidation and unification of these various models with an eye toward their implications for the entire question of cognitive objects and models of cognitive activity. The notion of a 'physical symbol' as a model for cognitive objects may be too narrow. This conference explored this set of issues by bringing together both experimentalists and theoreticians. The conference fostered a general understanding of dynamic models and both their limitations as well as their potential to explicate high-level cognitive phenomena.

## Manuscripts and Abstracts

Port, R. and van Gelder, T. (1991). Representing aspects of language. *Proceedings of the Cognitive Science Society* **13**, (Lawrence Erlbaum, Hillsdale, NJ) pp. 487-492.

Port, Robert (1990) Representation and recognition of temporal patterns. *Connection Science*, 151-176.

Port, Robert F. (1992) Review of 'Readings in Cognitive Science' by A. Collins and E. E. Smith. *Journal of Mathematical Psychology* (in press June, 1992).

Port, Robert (1991) Dynamic output is not enough. *Neural Network Review*

Merrill, John W. L. and Robert Port (1991) Fractally configured neural networks. *Neural Networks* **4**, 53-60.

Port, Robert F. (1990) Review of 'Readings in Cognitive Science' by A. Collins and E. E. Smith. *Journal of Mathematical Psychology* (in press).

Presentations

Port, R. and van Gelder, T. (1991). Dimensions of difference: Compositional representations in AI and connectionism. *Cognitive Science Research Report* **40** (IU Cognitive Science Program, Indiana University, Bloomington, Indiana).

# VII. Speech Research Laboratory

D.B. Pisoni

Ongoing research in the Speech Laboratory is concerned with a wide range of basic and applied problems in spoken language processing. All of these include research on speech analysis, synthesis and perception. Several recent projects have been concerned with spoken word recognition and lexical access as well as spoken language comprehension.

A long-standing research interest has been the development of evaluation and assessment techniques to study the perception of synthetic speech produced by rule. Studies of phoneme intelligibility, word recognition in sentences and comprehension are carried out to learn more about the differences in perception between natural speech and various kinds of synthetic speech produced automatically by rule using several text-to-speech systems. This work also involves studies designed to examine speech perception under high information load conditions, in order to learn more about how listeners allocate processing resources when the signals do not contain the redundancy of natural speech. Other studies are concerned with developing new methodologies to assess the real-time comprehension of fluent passages of connected synthetic speech produced by rule.

We have been working on a variety of issues related to variability in speech perception, particularly variability related to differences in speaking rate and differences among talkers. Our recent findings have shown that very detailed information about talker and rate variability is encoded into representation in long-term memory. These results raise a number of important issues about perceptual normalization in speech and the role of source characteristics in encoding and representation of phonetic information in memory.

Finally, we have a long-standing interest in perceptual learning, particularly as it might be applied to the reacquisition of non-native phonological distinctions. A major project has been concerned with the acquisition of English /r/ and /l/ by native speakers of Japanese.

The Speech Laboratory is well-equipped with extensive hardware and software for presenting complex acoustic signals to subjects and recording their responses in real-time. Three PDP-11/34 computers are used for perceptual experiments with human observers. There are also extensive computer resources for analyzing acoustic waveforms and generating experimental signals with a variety of speech synthesizers. In addition to the PDP-11/34 minicomputers, the lab currently has a dedicated DEC VAX-11/750 computer system and three DEC VAX work stations that serve as dedicated speech processing stations. The SRL VAX serves as the main computing facility for researchers in the Speech Lab. Each member of the laboratory has a CRT terminal at his/her desk. Additional graphics terminals are located throughout the lab and in several offices in the Psychology building. All computing facilities in the lab are interconnected using Ethernet. In addition, the Speech Lab VAX is interconnected to the campus computing system to facilitate transfer of files to colleagues in other laboratories, both on campus and at other institutions.

Detailed reports of research in the Speech Lab are not included here, in part because that work is more fully described in the annual progress report series entitled *Research on Speech Perception.* Institutions and individuals may obtain copies from the Administrative Assistant, Speech Research Laboratory, Department of Psychology, Indiana University, Bloomington, Indiana 47405.

Research in the Speech Lab has been supported by grants from NIH and NSF and contracts from the U.S. Air Force Office of Scientific Research.

# VIII. Visiting Scientists in Human Factors:

**Andrew P. Dillon**

*1. Individual differences*

An extensive literature review on the subject of individual differences in human information processing was carried out over the duration of the visit. This was coupled with regular meetings between Drs. Watson and Dillon to discuss the area and direct the review process. This work aimed at bridging the gap between traditional differential psychology and an emerging literature on individual differences in sensory and cognitive psychology, as well as identifying potential applications of this research in personnel selection in both military and commercial domains. A report outlining the findings of this review is in preparation, and will be presented for publication in due course.

**Individual Differences, Human Information Processing and Personnel Selection**
Abstract of Review Article by Andrew Dillon and C.S. Watson

The study of individual differences is as old as psychology itself, however most writers trace its historical roots to turn-of-the-century work on intelligence and ability testing by people such as Thorndike, Binet and Spearman. Almost one hundred years later it is clear that the domain of differential or correlational psychology has largely evolved separately from the experimental tradition so much so that writers as early as Boring (1929) and as recent as Jenkins (1989) refer regrettably to the two approaches as distinct disciplines within psychology, each concerned with different issues and employing different methods, often with little interaction between them.

Most noticeable is the difference in what Thorndike (1954) termed the "laboratory values" of these approaches. The differential approach is characterized by large sample sizes and the rigorous application of multivariate or factor-analytic techniques in the search for identifiable patterns of differences within the samples. For the differentialist, variations from the mean are thought to reflect latent mental structures or "factors" required to perform a task. The experimentalist however is less concerned with sample sizes and typically assumes relative homogeneity among subjects of whatever ability is required to perform a task, often relegating inter-subject differences into the category of error variance. Where individual differences are of interest, for the contemporary experimentalists at least, process (how a psychological event occurs) rather than structure (what psychological factors are employed) in task performance is its most important determinant.

The two disciplines can be bridged. Adams (1989) argues that the field of learning has always attempted to draw on the two approaches, if only as a result of the continuous debates about the relationship between intelligence and learning (see. e.g., Thorndike 1926, Gagne 1967). As will be shown, some investigators are beginning to take an interest in individual differences in human information processing and are applying differential concepts to experimental investigations (e.g., Dillon and Schmeck 1983, Sternberg 1985). Practically, such a marriage of correlational and experimental psychology has had demonstrated value for the selection of personnel in any number of situations. For example, as Overmier et al (1989) point out: the US Navy teaches over 7000 courses per annum to about 900 000 students. With failure rates for unselected samples often reaching 50%, any theory-based knowledge of the influence of instruction type on individuals of varying abilities becomes critically important. Similar arguments can be made for selection in a wide variety of

industrial or commercial scenarios also.

Personnel-selection issues are likely to increase in importance in the future as technological developments change the nature of much routine work from predominantly physical to more cognitive activities. Coupled with rapid changes in technology, prediction of performance (and also the successful design of systems) must be based on the relation of human information processing abilities to work tasks and to the range of individual differences in these abilities.

This review examines the dominant themes of current differential psychology and discusses some of the efforts to apply an experimental approach to the study of individual differences in human cognitive abilities. It then examines the the previously attempted as well as the potential applications of this work to problems of personnel selection.

2. *Human Factors in the design of educational technology*

With members of the Department of Instructional Systems Technology (IST) and the Center for Media and Teaching Resources (CMTR) the question of usable technology in training and educational environments has been pursued through a series of regular meetings and workshops. Focusing on hypermedia applications, an attempt has been made to relate human factors approaches to system design (particularly models and techniques from the study of cognitive ergonomics and human-computer interaction) to instructional theory.

In particular, a group was formed by Dillon and members of CMTR to exchange literature and ideas on the similarities and differences between design and learning as viewed by psychologists working within the cognitive psychology paradigm with constructivist approaches to learning which are predicated on entirely different models of information and knowledge (i.e., they reject the idea of humans as information processors and emphasize the social and environmental nature of human learning and performance). This work had an impact on several ongoing design projects at CMTR and will be written up in a form suitable for publication.

With IST staff and students Dillon helped develop a prototype interface for a hypermedia system to train medical staff involved in the treatment of diabetes. This prototype formed the basis of a research grant proposal to NIH through the Diabetes Research and Training Center at IU School of Medicine (initial feedback suggests funding is likely). Dillon also contributed to the writing of a research proposal submitted to Eli Lilly and Co. by Dr. David Marrero of the School of Medicine.

With Dr. Thomas Duffy of the Dept. of IST, Dillon has pursued the problem of empirically distinguishing between human factors and constructivist approaches to technology design. These discussions are likely to lead to maintained contact and possible joint research on the design of usable systems.

3. *Miscellaneous*

Dillon was an invited speaker at the School of Library and Information Studies Workshop on Human Computer Interaction where he lectured on Human Factors in Information Usage and Design on May 24, 1992. In addition, occasional meetings between Drs. Shaw and Davis of SLIS and Dillon have led to the reformulation of a study of humanities scholars usage of library resources

planned for this summer at IU.

Dillon was a member of, and named co-author of *ACPC Multimedia Application Area Plan*, a report from the University Planning Committee on multimedia in education, .

Dillon has been an advisor to the Financial Management Services group at IU on the development of a user interface for a new computerized financial management system for university use.

During his visit, Dillon has been working intermittently on *Designing Usable Electronic Documents*, a book to be published in 1993 by Taylor and Francis, London. The author is grateful for the time here that enabled aspects of this text to be developed and will duly acknowledge the Institute in the finished text.

## Manuscripts

Dillon, A. (1992) *Electronic text as cognitive artifact.* Paper presented at the 2nd Annual Conference of the Society for Text and Discourse, San Diego, June.

Dillon, A. (in press). Reading from paper versus screens: a critical review of the empirical literature. *Ergonomics: 3rd Special Issue on Cognitive Ergonomics.*

# Other Sources of Support

**Auditory Research**

| | |
|---|---|
| AFOSR 87-0300<br>9/1/87-9/30/90 | Perception of Complex Auditory Patterns<br>C.S. Watson - $390,411 |
| NIH (NIDCD) R01 DC 00250<br>12/1/87 - 11/30/92 | Discrimination and Identification of Auditory Patterns<br>C.S. Watson - Total Direct Cost, Year 3: $79,913 |
| NIH<br>4/1/91 - 3/31/96 | Dynamic Attending and the Perception of Patterns in Time<br>G.R. Kidd - $321,317 |
| NIH (NIA) RO1 AG8293<br>5/1/90 - 4/30/95 | Speech Recognition by the Hearing-Impaired Elderly<br>L. E. Humes - $530,000 |
| NIH (NIDCD) RO1-NS14709<br>(subcontract)<br>7/1/89 - 6/30/96 | Frequency Analysis in Normal and Impaired Listeners<br>L.E. Humes - $188,792 |
| ONR<br>12/1/90 - 11/30/93 | Models for Continuous Auditory Processing<br>R. Port - $322,390 |
| NIH (NIDCD) R43 DC00893<br>7/18/90-1/17/91 | Indiana Speech Training Aid: Stage 2<br>D. Kewley-Port - $49,828 |
| Indiana Corporation for Science & Technology<br>2/1/91 - 11/30/91 | Indiana Speech Training Aid: Stage 3<br>D. Kewley-Port - $44,566 |

**Vision Research**

| | |
|---|---|
| National Eye Institute,<br>PHS #R03 EY07638-01<br>4/1/88-3/31/90 | Perceptual Aliasing in Human Amblyopia<br>A. Bradley - Direct costs $24,981 |
| Indiana University Intercampus Fund<br><br>7/90-7/91 | Evaluation of Potential Visual Function in Cataract Patients<br>A. Bradley, L. Casser, L.Thibos - Direct Costs $5,000 |
| Anti-reflection Coating Council of America<br>7/90-7/91 | A Visual Evaluation of Anti-reflection Coatings<br>A. Bradley, Ross - Direct costs $10,000 |
| NASA Ames Research Center,<br>Moffett Field, CA<br>6/91-5/92 | Visual Capabilities with Night Vision Goggles<br>A. Bradley - $16,000 |

NIH (NEI) R01-EY05109
4/1/89 - 3/31/91

Functional Analysis of Retinal Ganglion Cells
L. Thibos - Direct costs $59,477

NIH (PHS) SO7 RR7031 L
Biomedical Research Grant
11/89 - 3/31/91

Change of Perspective with Eyeball Rotation and Near Space Perception
G. Bingham - $9905

NSF

2/1/91 - 1/31/94

Physical Constraints on Form: Investigating Visual Information for Event Recognition and the Judgement of Sizes
G. Bingham - $175.000

I.U. Dean of Faculties Ventures Fund Award

4/3/92 - 4/3/93

A Study Group on Dynamical Systems Multidisciplinary in Cognitive Sciences
Bingham, Port, van Gelder, and Thelen - $2,500

Silor Corporation

Effect of New Lens Design on Vision of Musicians A. Bradley, Ross - $11,000

**Cognition and Decision Making Research**

NIH2R01MH12717
12/1/85 - 11/30/89

Information Processing, Search and Retrieval
R.M. Shiffrin - $240,604

NSF BNS 8710163
9/1/87- 8/31/90

Research on Identification of Mental System Architecture
James T. Townsend - $164,915

NIH PHS R01DC00095-21
7/1/86 - 6/30/93

Cutaneous Pattern Perception
J. C. Craig - $997, 361

NIH PHS NIDCD DC00-111-16
3/1/88 - 2/28/95

Speech Perception and Spoken Word Recognition
D. B. Pisoni - $1,637,392 (Total direct costs)

**Bioacoustic Research**

NSF BNS 87-20192
2/1/88 - 7/31/91

Sonar Tracking of Moving Targets by Echolocating Bats
R. Suthers - $267,151

NIH 1 RO1 NS29467-01

5/1/91 - 4/30/94

Motor Control in Production and Development of Birdsong
R. Suthers - $87,930 (Direct costs - Yr. 1)

**Connectionism**

IU Dean of Faculties Ventures Fund

Spring 1990 - Spring 1991

A Simulation of the Emergence of Multidisciplinary the concept of Same
M. Gasser - $1750

NSF BBS
1992 - 1994

A Connectionist Model of the Development of Similarity
M. Gasser, L. Smith - $173,125

NSF Young Investigator
1992 - 1997

M. Gasser - $125,000

ONR N0001491J-1261
12/1/1990 - 11/30/1993

Models for Continuous Processing of Auditory Signals
R. Port - $460,000

ONR N0001492-J1029
11/20/91 - 10/30/92

Conference on Dynamic Models of Cognition
R. Port - $7700

# Extramural Activities

C. S. Watson is the director of the Institute for the Study of Human Capabilities and serves as an advisor to the National Research Council's Committee on Hearing, Bioacoustics and Biomechanics (CHABA). He recently served as chairman of CHABA Working Group 95, on Personal Speech Perception Aids for the Hearing Impaired. He is also a member of ASA Standards Committees S3-63 on Acoustical Warning Devices, and S3-76 on Computerized Audiometry. Watson serves as a reviewer for the *Journal of the Acoustical Society of America, Journal of Speech and Hearing Research, and Perception and Psychophysics.*

R. M. Shiffrin serves as the associate director of the Institute for the Study of Human Capabilities. He is the first director of the Indiana University Cognitive Science program and serves on the National Science Foundation review panel for Cognition and Perception. He is consulting editor for *Acta Psychologia, Memory & Cognition, Psychological Review, and Journal of Mathematical Psychology.*

G. P. Bingham is a consulting editor for *Ecological Psychology,* and an associate for *Behavioral and Brain Sciences.* He serves as a referee for the *Journal of Experimental Psychology: Human Perception and Performance; Journal of Motor Behavior; Ecological Psychology; Behavioral Research Methods, Instruments, and Computers; Human Movement Science and for the National Science Foundation, division of Neural and Behavioral Sciences, Program in Language, Cognition, and Social Behavior; Human Factors; Memory and Cognition; Developmental Psychobiology.* He is a member of the Psychonomic Society, Sigma Xi, the International Society for Ecological Psychology, and the American Psychological Society.

A. Bradley serves as editorial reviewer for the *Journal of Neurophysiology, American Journal of Optometry and Physiological Optics, Vision Research, Journal of the Optical Society of America, Clinical Vision Research, Investigative Opthalmology and Visual Science, Ophthalmic and Physiological Optics, Gordon Heath Symposium Papers, Butterworths Scientific Publishers, Optometry and Vision Science, Behavior Research Methods, Instruments, & Computers, Developmental Psychobiology.* He is also grant reviewer for National Science Foundation and NIH. He was recently appointed to the editorial group of the "Dictionary of Visual Science" and served as 1992 General Chair of the Optical Society of America topical meeting: Non-invasive Assessment of the Visual System. He was awarded the Glen Fry Award for Visual Science by the American Academy of Optometry in December, 1991; he received the Best Paper Award for 1991 by the Society for Information Display. He is currently writing a book for Optometry students studying for their National Board Exams.

N. J. Castellan, Jr. is the editor of *Behavior Research Methods, Instruments, and Computers and Judgment/Decision Making,* a newsletter. He serves on the editorial boards of *Organizational Behavior and Human Decision Processes, Behavioral Decision Making, Social Science Computer Review, and Interactive Learning International* . He is chair of the Forum on Research Management, one of three standing committees of the Federation of Behavioral, Psychological and Cognitive Sciences.

J. C. Craig recently completed a three-year tenure as Associate Director of the Institute for the Study of Human Capabilities. He serves as a member of special review panels of NSF, NIH, and SBIR as well as having been a member of the NIH Study Section on Sensory Disorders and Language. He recently served on the Task Force on the National Strategic Research Plan for the new National Institute on Deafness and Other Communication Disorders. He is the recipient of the NIH's Javits Neuroscience Investigator Award, July, 1986 - June 1993.

M. Gasser served as co-organizer of Midwest Connectfest, a meeting of connectionist researchers in the Midwest. He is a member of AAAI, Association for Computational Linguistics, ACM, Cognitive Science Society, Midwest AI and Cognitive Science Society, Linguistic Society of America, and International Neural Network Society. He has served on the review panel of *Neural Information Processing Systems, Psychological Review, Studies in Second Language Acquisition, and Machine Learning.*

S. L. Guth is an ad hoc member of the U.S. Committee of the International Commission on Illumination and a Fellow of the Optical Society of America. He is a referee for grant proposals submitted to NIH and NSF as well as a referee for articles submitted to *Journal of the Optical Society of America, Vision Research, Psychological Review, Journal of Experimental Psychology, Perception, Journal of Color Research and Application, Perception & Psychophysics, and Science.* Dr. Guth has a strong affiliation with the vision group at the Laboratory of Applied Physics of the French Center for Scientific Research in Paris, where he maintains collaboration with Hans Brettel and Francoise Vienot on research that is related to his color perception and visual adaptation model.

L. E. Humes continues to serve on the Advisory Board of the American Academy of Audiology, on the Editorial Board of the *Journal of the American Academy of Audiology,* and as a member of the Executive Committee of CHABA.

D. Kewley-Port has just finished her tenure as Associate Editor for *Speech Processing and Communication Systems of the Journal of the Acoustical Society of America.* She referees grant proposals for NSF and has served as a member of several NIH review panels. She also reviews manuscripts for *The Journal of Speech and Hearing Research, IEEE Transactions on Acoustic, Speech and Signal Processing, and Computer Users in Speech and Hearing.*

G. Kidd is a member of the American Psychological Society, the Acoustical Society of America, the International Society for Ecological Psychology, and an associate member of the Psychonomic Society. He has reviewed manuscripts for *Journal of Experimental Psychology: Human Perception and Performance, Language and Speech, Journal of the Acoustical Society of America, and American Journal of Psychology.*

D. P. Maki is a member of the American Mathematical Society, the Society for Industrial and Applied Mathematics, and the Acoustical Society of America and is a Governor of the Mathematical Association of America.

D. B. Pisoni is director of the Speech Research Laboratory at Indiana University. He serves on the editorial boards of *Computer Speech and Language and Speech Technology.* He is a recipient of the Jacob K. Javits Neuroscience Investigator Award (1987-1995).

R. F. Port is a member of the Linguistic Society of America, the Acoustical Society of America, the Association for Computational Linguistics, and the International Neural Network Society. He reviews manuscripts for the *Journal of the Acoustical Society of America, the Journal of Speech and Hearing Research, Perception and Psychophysics, and the Journal of Phonetics.*

D. E. Robinson continues to serve as a scientific advisor to CHABA and on the Science Advisory Board of the Parmly Hearing Institute, Loyola University, Chicago. He has reviewed papers for the *Journal of the Acoustical Society of America, the Psychological Bulletin, and Developmental Psychobiology. Manuscripts and Abstracts.*

R. A. Suthers is on the editorial board of Experimental Biology and is a reviewer for the *Journal of Comparative Physiology, Ethology, Animal Behavior, Science, Behavioral Ecology & Sociobiology, and the Canadian Journal of Zoology.* He has been an invited lecturer at numerous national and international symposia.

L. N. Thibos serves as editorial reviewer for the *Journal of the Optical Society of America, Optometry and Vision Science, and Vision Research* and as grant reviewer for the Air Force Office of Scientific Research, the National Science Foundation and the National Health and Medical Research Council of Australia. He is a member of the national program committee for the annual meeting of the American Academy of Optometry.

J. T. Townsend recently finished his tenure as *Editor of the Journal of Mathematical Psychology,* as well as his term on the Executive Board of the Society of Mathematical Psychology. He previously served as President of the Society of Mathematical Psychology. He continues to serve as *Associate Editor of Journal of Mathematical Psychology* and is a member of many professional societies including: Psychonomic Society, Society for Mathematical Psychology, Society for Judgment and Decision Making, International Neural Network Society, and Mathematical Association of America. Dr. Townsend serves as an editorial consultant and reviewer for a number of journals and granting agencies.

# Bibliography

**The following is a cumulative list of archival publications by Institute investigators from January, 1987 -May 31,1992.**

**1987**


1. Berg, B.G. (1987). Internal noise in auditory detection tasks. Ph.D. dissertation, Indiana University.

2. Dorffner, G. Kwasny, S. and Port, R. (1987). Parsing phonetic segments into syllables. In E. Buchberger and J. Retti (eds.), *Proceedings of the Third Austrian Artificial Intelligence Conference*. Springer-Verlag, Bonn, 49-63.

3. Espinoza-Varas, B. and Watson, C.S. (1987). Perception of complex auditory patterns by humans. In S.H. Hulse and R.J. Dooling (eds.), *The Comparative Psychology of Complex Acoustic Perception.*

4. Espinoza-Varas, B. (1987). Involvement of the critical band in identification, perceived distance, and discrimination of vowels. In M.E.H. Schouten (ed.), *The Psychophysics of Speech Perception.* M. Nijhoff, The Netherlands, 306-313.

5. Hartley, D.J. and Suthers, R.A. (1987). The sound emission pattern and the acoustical role of the noseleaf in the echolocating bat, *Carollia perspicillata. J. Acoust. Soc. Am.*, **8**, 1892-1900.

6. Humes, L.E., Boney, S. and Loven, F. (1987). Further validation of the Speech Transmission Index (STI). *J. Speech Hear. Res.*, **30**, 703-712.

7. Humes, L.E., Dirks, D.D., Bell, T.S. and Kincaid, G.E. (1987). Recognition of nonsense syllables by hearing-impaired listeners and noise-masked normal hearers. *J. Acoust. Soc. Am.*, **81**, 765-773.

8. Kewley-Port, D., Watson, C.S. and Cromer, P.A. (1987). The Indiana Speech Training Aid (ISTRA): A microcomputer-based aid using speaker-dependent speech recognition. *Synergy '87 Proceedings*, American Speech and Hearing Foundation, 94-99.

9. Kewley-Port, D., Watson, C.S., Maki, D. and Reed, D. (1987). Speaker-dependent speech recognition as the basis for a speech training aid. *Proceedings of the 1987 IEEE International Conference on Acoustics, Speech, and Signal Processing.* Dallas, TX, 372-375.

10. Port, R., Reilly, W. and Maki, D. (1987). Using global timing to discriminate words. *J. Acoust. Soc. Am.*, **83**, 256-273.

11. Schurr, R.L. and Suthers, R. (1987). Respiratory patterns during song production in the canary. *The Physiologist*, **30**(4), 221.

12. Smythe, E. J. (1987). The detection of formant transitions in a connectionist network. *Proceedings of the First IEEE International Conference on Neural Networks.* University of California, San Diego, 495-503.

13. Sorkin, R.D., Robinson, D.E. and Berg, B.G. (1987). A detection theory method for the analysis of visual and auditory displays. *Proceedings of the 31st Annual Meeting of the Human Factors Society*, **2**, 1184-1188.

14. Thibos, L.N. (1987). Calculation of the influence of lateral chromatic aberration on image quality across the visual field. *J. Opt. Soc. Am.* **A**, 4, 1673-1680.

15. Thibos, L.N., Bradley, A., Still, D.L. and Henderson, P. (1987). Do white-light interferometers bypass the eye's optics? Clinical implications of decentering the optical beam in the pupil. *Optical Society of America Technical Digest:* Topical meeting on noninvasive assessment of the visual system, 80-82.

16. Thibos, L.N., Cheney, F.E. and Walsh, D.J. (1987). Retinal limits to the detection and resolution of gratings. *J. Opt. Soc. Am.* **A**, 4, 1524-1529.

17. Thibos, L.N., Walsh, D.J. and Cheney, F.E. (1987). Vision beyond the resolution limit: Aliasing in the periphery. *Vision Res.*, **27**, 2193-2197.

18. Watson, C.S. (1987). Uncertainty, informational masking and the capacity of immediate auditory memory. In W.A. Yost and C.S. Watson (eds.), *Auditory Processing of Complex Sounds.* Erlbaum Associates, Hillsdale, NJ.

19. Wilde, G. and Humes, L.E. (1987). Measurement of the attenuation characteristics of nonlinear hearing protective devices using the auditory brainstem response. *J. Acoust. Soc. Am.*, **81**, 730-733.

20. Yost, W.A. and Watson, C.S. (eds.) (1987). *Auditory Processing of Complex Sounds.* Erlbaum Associates, Hillsdale, NJ.

**1988**

21. Anderson, S., Merrill, J. and Port, R. (1988). Speech analysis using sequential networks. G. Hinton, T. Sejnowski and D. Touretzky (eds.), *Proceedings of Carnegie-Mellon University Summer Institute on Connectionism.* Morgan Kaufman, San Mateo, CA.

22. Bradley, A., Switkes, E. and De Valois, K.K. (1988). Orientation and spatial frequency selectivity of adaptation to color and luminance gratings. 23.

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173. Bradley, A. Zhang, X. X. and Thibos, L. N. (1992). Failures of isoluminance caused by ocular chromatic aberrations. *Applied Optics* (in press).

174. Bradley, A. (1992). Glen Fry Award Lecture: Perceptual manifestations of imperfect optics in the human eye: Attempts to correct for ocular chromatic aberration. *Optom. Vis. Sci.* (in press).

175. Czerwinski, M., Lightfoot, N., & Shiffrin, R. M. (in press). Automatization and training in visual search. *American Journal of Psychology.*

176. Dillon, A. (in press). Reading from paper versus screens: a critical review of the empirical literature. *Ergonomics: 3rd Special Issue on Cognitive Ergonomics.*

177. Evans, P.M., Craig, J.C., and Rinker, M.A. (In press). Perceptual processing of adjacent and nonadjacent tactile nontargets. *Perception & Psychophysics.*

178. Humes, L.E., Nelson, K.J., and Pisoni, D.B. (In press). Recognition of synthetic speech by hearing- impaired elderly listeners. *J. Speech Hear. Res.*

179. Humes, L.E. and Jesteadt, W. (In press). Models of the effects of threshold on loudness growth and summation. *J. Acoust. Soc. Am.*

180. Kidd, G. R., & Watson, C. S. The "proportion-of-the-total-duration (PTD) rule" for the discrimination of auditory patterns. *Journal of the Acoustical Society of America,* (accepted January 1992).

181. Lightfoot, N., & Shiffrin, R. M. (in press). On the unitization of novel, complex visual stimuli. Proceedings of the Fourteenth Annual Conference of the Cognitive Science Society. Hillsdale, NJ: Lawrence Erlbaum Associates.

182. Muchisky, M.M. & Bingham, G.P. (1992). Perceiving size in events via kinematic form. *Proceedings of the 14th Annual Conference of the Cognitive Science Society.* Forthcoming.

183. Port, Robert F. (1992) Review of 'Readings in Cognitive Science' by A. Collins and E. E. Smith. *Journal of Mathematical Psychology* (in press June, 1992).

184. Rahman, H. A., Bradley, A., Soni. S. and Zhang, X. (1992) Letter contrast sensitivity with simultaneous vision bifocal contact lenses. *Optom. Vision Sci.* (submitted).

185. Romack, J.L., Buss, R.A. & Bingham, G.P. (1992). 'Adaptation' to displacement prisms is sensorimotor learning. *Proceedings of the 14th Annual Conference of the Cognitive Science Society.* Forthcoming.

186. Shiffrin, R. M., Czerwinski, M. P., & Lightfoot, N. (in press). On the automatization of visual search. In Izawa, C. (Ed.), *Cognitive Psychology Applied.* Hillsdale, NJ: Lawrence Erlbaum Associates.

187. Thibos, L. N. and Bradley, A. (1992). New methodologies for discriminating neural and optical losses of vision. *Optometry and Vision Science* (in press).

188. Ye., M., Bradley, A., Zhang, X. and Thibos, L.N. (1992). Effects of chromatic abberrations and the Stiles-Crawford effect on chromostereopsis. *Vision Research* (in press).

189. Zhang, X., Bradley, A., and Thibos, L. N. (1992). Experimental measurements of ocular chromatic difference of magnification and the anterior nodal point. *Opt. Soc. Am.* (submitted).

## Technical Reports and Abstracts of Papers Presented at Scientific Meetings

### 1988


1. Anderson, S., Merrill, J. and Port, R. (1988). Dynamic speech categorization with recurrent networks. In G. Hinton, T. Sejnowski and D. Touretzky (eds.), *Proceedings of 1988 Connectionist Summer School.* Morgan Kaufmann, San Mateo, CA, 398-406. 2.

2. Anderson, S., Merrill, J. and Port, R. (1988). Sequential networks as attentional systems. Presented at the first meeting of the International Neural Network Society.

3. Bradley, A., Zhang, X. and Thibos, L.N. (1988). Retinal image isoluminance is compromised by lateral and longitudinal chromatic aberration. *J. Opt. Soc. Am.* **A4**, (suppl.).

4. Bradley, A and Thibos, L.N. (1988). Perceptual aliasing in human amblyopia. *Invest. Ophthal. Vis. Sci.*, **29** (suppl.), 76.

5. Guth, S.L. (1988). Color Theory. Abstract submitted SPSE/SPIE Symposium on Electronic Imaging. Jan. 15-20, 1989, Los Angeles.

6. Hartley, D.J. and Suthers, R.A. (1988). The filter function of the supraglottal vocal tract and the acoustic role of the vocal tract chambers in the horseshoe bat. *Association for Research in Otolaryngology.* 11th Midwinter Research Meeting.

7. Hirt, E.R., and Castellan, N.J., Jr. (1988). Fault trees: Category redefinition and context. Paper read at *Midwestern Psychological Association.* Chicago.

8. Kewley-Port, D., Watson, C.S. and Elbert, M. (1988). The Indiana Speech Training Aid (ISTRA). *J. Acoust. Soc. Am., Suppl. I,* **84**, S42. Presented at the *2nd joint meeting of The Acoustical Societies of America and Japan, Honolulu, Hawaii,* November.

9. Kewley-Port, D., Watson, C.S., Elbert, M. and Cromer, P. (1988). Indiana Speech Training Aid (ISTRA). *ASHA* **30**, 207. Scientific Exhibit presented at the 1988 Annual Convention of the American Speech-Language-Hearing Association, Boston, MA, November.

10. Port, R., Anderson, S. and Merrill, J. (1988). Temporal information and memory in connectionist networks. Technical Report 265, Indiana University Computer Science Department.

11. Smythe, E. (1988). *Temporal Computation in Connectionist Models. Department of Computer Science,* Indiana University, Technical Report No. 251. 13 pages.

12. Still, D.L. and Thibos, L.N. (1988). Aliasing is the difference between pattern detection and pattern resolution in peripheral vision. *Am. J. Optom. Physiol. Optics,* **65**. 122 pages.

13. Suthers, R.A. and Hartley, D.J. (1988). Subglottal chambers in the horseshoe bat affect vocal efficiency. *Association for Research in Otolaryngology.* 11th Midwinter Research Meeting.

14. Thibos, L.N. and Still, D.L. (1988). Aliasing and contrast sensitivity in peripheral vision. *J. Opt. Soc. Am.* **A4**, (suppl.).

15. Thibos, L.N. and Still, D.L. (1988). What limits visual resolution in peripheral vision? *Invest. Ophthal. Vis. Sci., 29 (suppl.),* 138.

16. Watson, C.S and Kewley-Port, D. Computer-Based Speech Training Aids. *J. Acoust. Soc. Am.*, Suppl. I, **84**, S42. Presented at the 2nd joint meeting of The Acoustical Societies of America and Japan, Honolulu, Hawaii, November, 1988.

17. Zhang, X., Bradley, A. and Thibos, L.N. (1988). Achromatizing lenses may increase chromatic aberration in the retinal image. *Invest. Ophthal. Vis. Sci.*, **29** (suppl.), 446.

18. Zhang, X., Bradley, A. and Thibos, L.N. (1988) Interaction between longitudinal and lateral chromatic aberrations in the retinal image. *J. Opt. Soc. Am.* **A4**, (suppl).

19. Zhang, X., Bradley, A. and Thibos, L.N. (1988) The beneficial effect of longitudinal chromatic aberration. *Am. J. Optom. Physiol. Optics,* **65**. 47 pages.

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20. Applegate, R.A., Bradley, A., Zeffren, B. and Van Heuven, W.A.J. (1989). Entoptic visualization of macular capillaries. Presentation at the 1989 Annual meeting of the American Academy of Optometry.

21. Applegate, R.A., Bradley, A., Zeffren, B. and Van Heuven W.A.J. (1989). Psycholphysical evaluation of the foveal avascular zone (FAZ) sizer and foveola location. *Invest. Ophthal. Vis. Sci.*, **30** (suppl.), 410.

22. Berg, B.G. and Robinson, D.E. (1989). Nonuniform utilization of information in multiple observation tasks. *Abstracts of Midwinter Research Meeting, Association for Research in Otolaryngology,* 301.

23. Bingham, G.P. (1989). Exploration of the relation between resource and task dynamics. An invited paper presented at the Workshop on Ecological Methods for Studying Perceptually-guided Action, Research Group on Mind and Brain, Center for Interdisciplinary Research, University of Bielefeld, Bielefeld, West Germany, December 1st.

24. Bradley, A. (1989). Achromatizing the human eye. Invited presentation at the 1989 Annual meeting of the American Academy of Optometry. *Optom. Vis. Sci.*, **66** (suppl.), 189.

25. Bradley, A., Applegate, R., Zeffren, B. and Van Heuver, W.J.A. (1989). Psychophysical evaluation of retinal vessels. *Opt. Soc. Am. Topical Meeting on Non-invasive Methods.*

26. Bradley, A., Thibos, L.N. and Zhang, X. (1989) Luminance artifacts in the retinal images of isoluminant color-modulated stimuli: Effect of correcting axial chromatic aberration. *Invest. Ophthal. Vis. Sci.*, **30** (suppl.), 507.

27. Cannon, M.W., Thibos, L.N. and Wilkinson, M.O. (1989). Why does spectacle magnification affect apparent contrast? Presentation at the 1989 Annual meeting of the American Academy of Optometry. *Optom. Vis. Sci.*, **66** (suppl.), 220.

28. Casser, L., McConnaha, D. and Bradley, A. (1989). Clinical assessment of clinical contrast sensitivity charts. Presentation at the 1989 Annual meeting of the American Academy of Optometry. *Optom. Vis. Sci.*, **66** (suppl.), 72.

29. Castellan, N.J., Jr. (1989). Integrating computers into the curriculum: Challenges and rewards. Invited presentation at Computing in Instruction '89," Minnesota Community Colleges. Brainerd, MN, August, 1989.

30. Craig, J. C. (1989). Capacities and limitations of tactile processing. The International Union of Physiological Societies Satellite Symposium,Information Processing in the Somatosensory System, Wenner-Gren Center, Stockholm, Sweden.

31. Craig, J.C. (1989). Tactile channels. Paper presented to the Psychonomic Society, November.

32. Evans, P.M. (1989). Cross-modal equivalence matching and the same-different reaction-time disparity. Paper presented to the Tactile Research Conference, Atlanta, GA, November.

33. Gasser, M. (1989). Robust lexical selection in parsing and generation. *Proceedings of the Eleventh Annual Meeting of the Cognitive Science Society.*

34. Gasser, M. (1989). Towards a connectionist model of the perception and production of rhythmic patterns. *Proceedings of the Second International Workshop on AI and Music*, 99-101.

35. Guth, S.L. (1989). Colorimetry and color vision. Invited seminar presented at the first meeting of Le Club Visu," Paris, France, Nov., 1989. (Le Club Visu includes the Centre Nationale d'Etudes des Telecommunications," the Society Francaise du Vide" and the "Society des Electricians, des Electroniciens et des Radioelectriciens.")

36. Guth, S.L. (1989). Color perception and visual adaptation. Invited seminar presented at the Centre Nationale des Recherches Scientifique, Paris, France, November.38.

37. Guth, S.L. (1989). Unified model for human color perception and visual adaptation. *Proc. SPIE.*

38. Guth, S.L. (1989). Model for color vision and adaptation. *Invest. Ophthal. Vis. Sci.*, **30** (suppl.), 219.

39. Hartley, D.J., Campbell, K.A. and Suthers, R.A. (1989). The acoustic behavior of the fishing bat *Noctilio leporinus* during prey capture. *Association for Research in Otolaryngology.* Abstracts of the 12th Midwinter Research Meeting, 234.

40. Jesteadt, W. and Humes, L.E. (1989). Effect of threshold on the growth of loudness at low frequencies. *J. Acoust. Soc. Am.*, **85**, S108.

41. Kewley-Port, D. (1989). Detection thresholds for isolated vowels. *J. Acoust. Soc. Am., Suppl. 1*, **85**, S51. Presented at the 117th meeting of the Acoustical Society of America, Syracuse, NY, May.

42. Kewley-Port, D. and Watson, C.S. (1989). Computer assisted speech training for the deaf. *ASHA, 31*, 55. Presented in miniseminar Speech of Persons Who are Hearing Impaired: Historical and Current Perspectives," at the 1989 Annual Convention of the American Speech-Language-Hearing Association, St. Louis, MO, November.

43. Kidd, G. R. and Watson, C. S. (1989). Detection of relative-frequency changes in tonal sequences. *J. Acoust. Soc. Am. Suppl.* 1., **86** , S121.

44. Port, R. and Anderson, S. (1989). Recognition of continuously performed melodies. *Proceedings of the 11th Annual Meeting of the Cognitive Science Society.* L. Erlbaum Assoc., Hillsdale, NJ.

45. Robinson, D. E. (1989). Analysis of classification systems. Final Report, Contract #N6053087-87-M-360D, Naval Weapons Center, China Lake, CA.

46. Still, D.L. (1989). The effect of image quality on contrast sensitivity and acuity in central and peripheral vision. Invited presentation at the 1989 Annual meeting of the American Academy of Optometry.

47. Still, D.L., Thibos, L.N. and Bradley, A. (1989) Peripheral image quality is almost as good as central image quality. *Invest. Ophthal. Vis. Sci.*, **30** (suppl.).

48. Suthers, R.A. and Hartley, R.S. (1989). Differential airflow through the right and left sides of the avian syrinx during song. *Association for Research in Otolaryngology.* Abstracts of the 12th Midwinter Research Meeting, 308.

49. Suthers, R.A. and Hartley, R. S. (1989). The relative contributions of the left and right sides of the intact syrinx to birdsong. *Soc. for Neuroscience Abstr.*, **15**, 619.

50. Thibos, L.N. (1989). The effect of ocular chromatic aberration on visual performance. Invited presentation at the 1989 Annual meeting of the American Academy of Optometry. *Optom. Vis. Sci.*, **66** (suppl.), 189.

51. Thibos, L.N., Bradley, A. and Still, D.L. (1989). Visual acuity measured with clinical maxwellian view systems: effects of beam-entry location. *Optical Society of America Technical Digest:* Topical meeting on noninvasive assessment of the visual system, **7**, 94-97.

52. Watson, C.S. and Kidd, G.R. (1989). Proportional target-tone duration as a limit on pattern discriminability: Multi-component targets. *J. Acoust. Soc. Am.*, **86** (suppl.), S23.

53. Weisenberger, J. M., Craig, J. C. and Abbott, G. D. (1989). Evaluation of a principal-components tactile speech aid. Presented at the meeting of the American Speech-Language-Hearing Association, St. Louis, MO, November.

54. Ye, M., Thibos, L.N, Bradley, A. and Zhang, X. (1989). Does retinal illuminance affect chromostereopsis? Presentation at the 1989 Annual meeting of the American Academy of Optometry.53.

55. Ye, M., Zhang, X., Bradley, A. and Thibos, L. (1989). Chromostereopsis: The interaction of transverse chromatic aberration, axial chromatic aberration and the Stiles-Crawford effect. *Invest. Ophthal. Vis. Sci.*, **30** (suppl.), 507.

56. Zhang, X., Bradley, A. and Thibos, L.N. (1989). An estimation of the contrast contamination introduced by correction of ocular chromatic aberration. *Invest. Ophthal. Vis. Sci.*, **30**, (suppl.), 219.

57. Zhang, X., Bradley, A. and Thibos, L.N. (1989). Theoretical analysis of the effect of chromatic aberration on chromatic appearance of isoluminant color gratings. Presentation at '89 Annual meeting of the American Academy of Optometry.

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58. Applegate, R.A., Elsner, A., Jalkh, A.E. and Bradley, A. (1990). Location of the point of retinal fixation within the foveal avascular zone. Presented at the Conference on Scanning Laser Ophthalmoscopy, Microscopy, and Tomography, November.

59. Applegate, R.A., Bradley, A. and Zillio, C. (1990). See 7 micron capillaries in your own eye. Presented at the Annual Meeting of the Optical Society of America, November.

60. Applegate R.A., van Heuven, W.A.J, Bradley, A. and Zeffren, B.S. (1990). Are current laser protocols endangering the fovea? Annual meeting of the Association for Research in Vision and Ophthalmology, May.

61. Applegate, R.A., Bradley, A. and van Heuven, W.A.J. (1990). Zapping the retinal point of fixation? Presented at the annual meeting of the American Academy of Ophthalmology, November.

62. Bingham, G.P. & Gutjahr, E.C. (1990). Perceiving the size of trees: An inkling of a solution to the scaling problem in event perception. An invited paper presented at a meeting of the *Midwestern Psychological Association* in Chicago, Il, May 4th.

63. Bingham, G.P. and Muchisky, M.M. (1990). Center of mass perception. A paper presented at a meeting of the International Society for Ecological Psychology at the Beckman Institute, University of Illinois, Urbana, Il, May 22.

64. Bingham, G.P. & Gutjahr, E C. (1990). Perceiving the size of trees: Reducing the problem of size perception to a problem of form perception. A paper presented at a meeting of the *International Society for Ecological Psychology* at the Beckman Institute, University of Illinois, Urbana, Il, May 22nd.

65. Bradley, A., Zhang, X. and Thibos, L.N. (1990). Experimental estimation of the chromatic difference of magnification of the human eye. *Invest. Ophthal. Vis. Sci.*, **31** (suppl.), 493.

66. Castellan, N.J., Jr. (1990). Decision Making: Processing Probabilistic Information. Presented to American Psychological Association, Boston, August.

67. Evans, P.M. (1990). Crossmodal pattern perception. Presented to the Psychonomic Society, New Orleans, LA, November.

68. Gasser, M. (1990). Reduplication and simple recurrent networks. First Midwest Connectfest, Bloomington, IN, November.

69. Gasser, M. and Lee, C.-D. (1990). A short-term memory architecture for learning morphophonemic rules. Third Conference on Neural Information Processing Systems, Denver, November.

70. Humes, L.E. (1990). Nonauditory factors affecting noise-induced hearing loss. NIH Consensus Conference of Noise-Induced Hearing Loss, Bethesda, MD.

71. Humes, L.E. (1990). Peripheral factors underlying the speech-recognition difficulties of hearing-impaired elderly. American Academy of Audiology, New Orleans, LA.

72. Humes, L.E. (1990). Prescribing gain characteristics of linear hearing aids. Vanderbilt/VA Symposium on Hearing Aids, Nashville, TN.

73. Humes, L.E. (1990). Loudness perception by the hearing-impaired elderly. CHABA Conference on Hearing and Aging, National Academy of Sciences, Washington, DC.

74. Humes, L.E. (1990). Application of the speech transmission index (STI) and articulation index (AI) to the hearing-impaired. Acoustical Society of America, San Diego, CA.

75. Kewley-Port, D. (1990). Cross-disciplinary advances in speech science. Presented at The Future of Science and Service Seminar, ASHA National Headquarters, October.

76. Kewley-Port, D. (1990). Thresholds for formant-frequency discrimination in isolated vowels. *J. Acoust. Soc. Am.*, **87** (suppl.), S159. Presented at the 119th Meeting of the Acoustical Society of America, State College, PA, May.

77. Kewley-Port, D., Watson, C.S. and Maki, D. (1990). Small Business Innovation (SBIR) Funding: A case study in bringing a computer-based speech training aid into the marketplace. *J. Acoust. Soc. Am.*, **88** (suppl.), S196. Presented at the 120th Meeting of the Acoustical Society of America, San Diego, CA, November.

78. Kidd, G. R. and Watson, C. S. (1990). Detection of relative-duration changes in tonal sequences. *J. Acoust. Soc. Am.*, **88** (suppl.), S147.

79. Mendell, L. L. and Castellan, N. J., Jr. (1990). Search strategies in sequential decision making: Information accumulation, search termination, and information presentation effect. Presented to Midwestern Psychological Assocation, Chicago, May.

80. Pickel, K. and Castellan, N. J., Jr. (1990). Juror's evaluations of relevant and irrelevant eyewitness testimony. Presented to Midwestern Psychological Association, Chicago, May.

81. Port, R. (1990). Perceiving sound patterns in time. Presented at the Center for the Study of Language and Intelligence (CSLI), Stanford University, March 22.

82. Port, R. (1990). Toward dynamic representation of sound patterns in networks. Presented at the Phonology Laboratory, Department of Linguistics, University of California, Berkeley, March.

83. Port, R. (1990). Connectionist models of auditory pattern perception. Presented to Department of Computer Science, Butler University, Indianapolis, April.

84. Port, R. (1990). Connectionist models for auditory pattern recognition. Presented at Central Institute for the Deaf, St. Louis, MO, October.

85. Port, R. (1990). Dynamic representations in connectionist models for audition. Presented to Department of Computer Science, Washington University, St. Louis, MO, October.

86. Port, R. (1990). Grounding of auditory symbols by means of dynamic auditory memory. Presented to Society for Psychology and Philosophy, University of Maryland, June.

87. Suthers, R.A. and Hartley, R.S. (1990). Effect of unilateral denervation on the acoustic output from each side of the syrinx in singing mimic thrushes. *Society for Neuroscience Abstracts* **16**(2) , 1249.

88. Thibos, L.N., Zhang, X. and Bradley, A. (1990). Effect of ocular chromatic aberration on the luminance modulation transfer function for white light in the reduced eye. *OSA Annual Meeting Technical Digest,* **15**, 148.

89. Thibos, L.N. (1990). The effect of ocular chromatic aberration on visual performance. Visual Science Symposium: Optical limits to visual performance. *Optom. Vis. Sci.*, **67** (suppl.), 167.

90. Thibos, L.N. (1990). Is the reduced schematic eye good enough?. Visual Science Symposium: Do we need a new schematic eye? *Optom. Vis. Sci.*, **67** (suppl.), 167.

91. Thibos, L.N. (1990). New methodologies for distinguishing between optical and neural losses in vision: The Second Monroe J. Hirsch Lecture on Vision Care. *Optom. Vis. Sci.*, **67** (suppl.), 83.

92. Thibos, L.N., Zhang, X., and Bradley, A. (1990). White-light modulation transfer functions of the reduced schematic eye. *Optom. Vis. Sci.*, **67** (suppl.), 56-57.

93. Wilkinson, M.O., Thibos, L.N. and Cannon, M.W. (1990). Contrast constancy: neural compensation for image attenuation. *Invest. Ophthal. Vis. Sci.*, **31** (suppl.), 323.

94. Ye, M., Bradley, A., Thibos, L.N. and Zhang, X. (1990). Effect of pupil apodization on apparent visual direction. *OSA Annual Meeting Technical Digest,* **15**, 91.

95. Ye, M., Bradley, A., Thibos, L.N., and Zhang, X. (1990). The role of the Stiles-Crawford effect in determining monocular visual direction. *Optom. Vis. Sci.*, **67** (suppl.), 57.

96. Zhang, X., Ye, M., Thibos, L.N., and Bradley, A. (1990). Retinal image contrast and the Stiles-Crawford Apodization. *Optom. Vis. Sci.*, **67** (suppl.), 57.

97. Zhang, X., Ye, M., Bradley, A. and Thibos, L.N. (1990). Stiles-Crawford effect improves defocused or aberrated retinal image quality. *OSA Annual Meeting Technical Digest,* **15**, 91.

98. Anderson, R., Wilkinson, M.O., and Thibos, L.N. (1991). Psychophysical localization of the human visual streak. *Invest. Ophthal. Vis. Sci.*, **32** (suppl.), 699.

99. Bingham, G.P. & Muchisky, M.M. (1991). Size perception in events. Presented at a meeting of the *International Society for Ecological Psychology* at Trinity College, Hartford, CT, October 19th.

100. Bingham, G.P., Muchisky, M.M. & Romack, J. (1991). 'Adaptation' to displacement prisms is sensorimotor skill acquisition. Presented at a meeting of the Psychonomic Society, San Francisco, CA, November 24th.

101. Bingham, G.P. & Muchisky, M.M. (1991). Center of mass perception for the visual guidance of grasping. A paper presented at the Conference on Human Error sponsored by the Institute for the Study of Human Capabilities at Indiana University, March 22nd.

102. Bingham, G.P. & Muchisky, M.M. (1991). Center of mass perception for the visual guidance of grasping: A GSD problem. Presented at the *6th International Conference on Event Perception and Action,* Amsterdam, August 29th.

103. Bingham, G.P. (1991). The identification problem in visual event perception. Presented at a Conference on Dynamic Representation in Cognition, Indiana University, Bloomington, IN, November 16th.

104. Bingham, G.P. (1991). Detection of accretion/deletion of optical texture at occluding edges produced by eye movement with head immobilized. Presented at a meeting of the Association for Research in Vision and Ophthalmology, Sarasota Springs, Florida, April 30th.

105. Bingham, G.P. (1991). Detection of accretion/deletion of optical texture at occluding edges produced by eye movement with head immobilized. Presented at the *6th International Conference on Event Perception and Action,* Amsterdam, August 30th.

106. Bingham, G.P. (1991). Why does optical pattern never look flat? (Or the demise of 'efference copy'). Presented at the Department of Psychology, Indiana University, Bloomington, IN, October 2nd.

107. Bradley A., Rahman, A., Soni, P.S. and Zhang, X., (1991) Through-focus measures of vision with 2-zone and diffractive bifocal contact lenses. *American Academy of Optometry Symposium on Simultaneous Bifocal and Multifocal Vision.*

108. Bradley, A., Thibos, L.N., Zhang, X., and Ye, M. (1991) The effects of ocular aberration on visual performance for displayed achromatic and chromatic information. In: *Digest of Technical Papers,* Society for Information Display, **22**, 304-307.

109. Bradley, A. and Applegate, R. A. (1991). Clinical value of the vascular entoptoscope. Presented at the Fergus Fest in Cambridge, England.

110. Bradley, A., and Thibos, L. N. (1991). Incorporating the eye's optics into an applied model of detection and identifiacation of objects: Presented to the *Armstrong Laboratory Advisory Group Conference* in San Antonio, TX.

111. Evans, P. M. and Craig, J.C. (1991). Identifying the direction of simulated movement on the skin. The effects of an irrelevant stimulus. Presented to the Acoustical Society of America, Baltimore, MD, May.

112. Evans, P.M. and Craig, J.C. Tactile attention and response competition. Presented to the Psychonomic Society, San Francisco, CA, November, 1991.

113. Gasser, M. (November, 1991) Phonological performance and sequential networks. Panel on Connectionism and Phonology. Second Annual Midwest Connectfest, Columbus, OH.

114. Kewley-Port, D. and Watson, C.S. (1991). 'Thresholds for formant-frequency discrimination of vowels in consonantal context." *J. Acoust. Soc. Am.*, **89**, 1996.

115. Mora, Juan Pablo, Robert F. Port and Catharina de Jonge (1991) Cross-language word identification using durational cues only. Paper presented at the Acoustical Society of America. *Journal of the Acoustical Society of America* **90**, (A) 2253.

116. Merrill, John W. L. and Robert Port (1991) Fractally configured neural networks. *Neural Networks* **4**, 53-60.

117. Port, Robert F. and van Gelder, T. (1991). Dimensions of difference: compositional representations in AI and connectionism. *Cognitive Science Research Report*, **40**, IU Cognitive Science Program, Indiana University, Bloomington, IN.

118. Port, Robert and Timothy van Gelder (1991) Representing aspects of language. *Proceedings of the Cognitive Science Society*, **13**, (Lawrence Erlbaum, Hillsdale, NJ) pp. 487-492.

119. Thibos, L.N. and Bradley, A. (1991). The limits to performance in central and peripheral vision. In: *Digest of Technical Papers, Society for Information Display*, **22**, 301-303.

120. Thibos, L.N., Zhang, X., and Bradley, A. (1991). The chromatic eye: A new model of ocular chromatic aberration. *Technical Digest on Ophthalmic and Visual Optics*, **2**, ThB1 1-4.

121. Thibos, L.N., Bradley, A., Wilkinson, M., and Cannon, M. (1991). New evidence for human errors in the perception of spatial patterns and contrast. Conference on Human Error, sponsored by Indiana Institute for the Study of Human Capabilities (March 20-22, 1991), 15-16.

122. Thibos, L.N., Zhang, X., Bradley, A. and Ye, M. (1991). Color-contrast modulation transfer functions and the effect of ocular chromatic aberration. *Invest. Ophthal. Vis. Sci,.* **32** (suppl.), 1210.

123. Thibos, L. N., Bradley, A. (1991). Fun with interferometers. Presented at the Fergus Fest in Cambridge, England. *Opthalmic Physiological Optics.*

124. Wilkinson, M.O., Thibos, L.N., and Bradley, A. (1991). Neural basis of scotopic acuity. *Invest. Ophthal. Vis. Sci.*, **32** (suppl.), 699.

125. Watson, C. S., Kidd, G. R., & Foyle, D. (1991). The proportion-of-the-total-duration (PTD) rule for auditory pattern discrimination. Presented at the third annual convention of the American Psychological Society. Washington, D.C., June 1991.

126. Zhang, X., Thibos, L.N., Bradley, A., and Ye, M. (1991). Modelling effects of defocus on human eyes with large pupils. *Invest. Ophthal. Vis. Sci.*, **32** (suppl.), 1211.

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127. Bingham, G.P., Romack, J.L. & Buss, R.A. (1992). 'Adaptation' to displacement prisms is sensorimotor skill acquisition. Presented at the Conference on Human Error sponsored by the Institute for the Study of Human Capabilities at Indiana University, Bloomington, IN, March 26th.

128. Bingham, G.P. & Muchisky, M.M. (1992). Perceiving size in events. Presented at the Department of Psychology, Indiana University, Bloomington, IN, April 1st.

129. Bingham, G.P. (1992). Perceiving the size of trees via their form. Presented at the Department of Psychology, Indiana University, Bloomington, IN, April 15th.

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